Scientific Voyage
Vol. 1, No. 3,
Page 1-20 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Jul.-Sep.

Ceramics and glasses for energy technologies

Himadri Sekhar Maiti
Project Adviser, Govt. College of Engineering and Ceramic Technology, Kolkata &
Former Director, CSIR-Central Glass and Ceramic Research Institute, Kolkata
Email: *hsmaiti2009@gmail.com*

Abstract: Energy technology is one the high priority areas of research and development, primarily due to rapid depletion of the existing resources of energy and their deleterious effect on the environment. Several of the emerging energy technologies, having higher conversion efficiency and higher energy/ power density are based on some of the unique properties of a few ceramic and glassy materials both in the areas of energy conversion and storage. Examples are Solid Oxide Fuel Cell (SOFC) based on oxygen ion conducting solid electrolyte and electronically conducting anodic and cathodic current collectors, lithium ion battery in which lithium intercalated cobalt oxide is used as the cathode material, sodium sulphur battery for which sodium ion conducting beta alumina is the electrolyte material, energy harvesting based on piezoelectric ceramics and clean coal technology, which make use of the porosity and high temperature resistance of silicon carbide ceramics. Their basic principles and application potentialities are briefly discussed here with emphasis on the materials aspect in each case.

Keywords: Energy, environment, ceramics, glasses, solid oxide fuel cell, lithium ion battery, sodium-sulphur battery, energy harvesting, clean coal technology.

1. Introduction

Human civilization has travelled a long distance since the pre-historic days. It has reached the current stage primarily because there has been availability of different sources of energy at different stages of its journey. Initially it was wood from the greeneries on the surface of the earth. At a later stage, it became the fossil fuels in the form of solid coal, liquid crude oil or the gaseous fuel e.g. natural gas; all from the underground. Even today these fossil fuels continue to be the major sources of energy for the sustainable growth of human civilization. It is evident from Fig. 1 that the world energy consumption has continuously increased over the years, which is around 5 times in a period of 50 years (1965-2015).

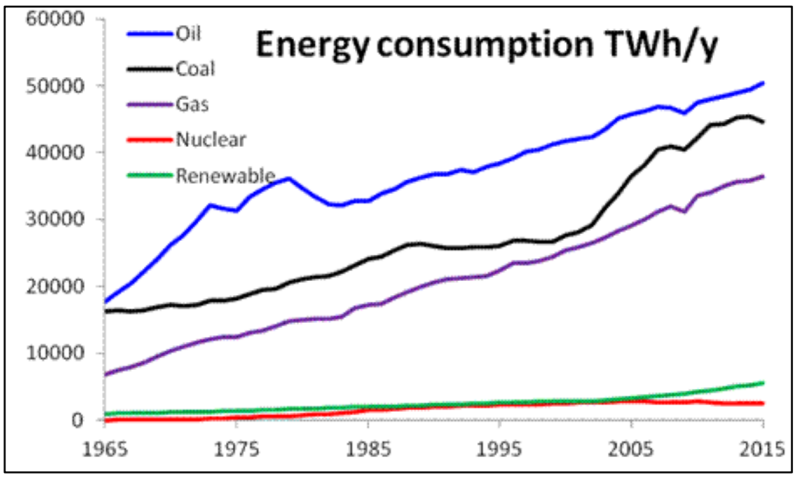


Fig. 1: World energy consumption over a period of 50 years [1]

The role of energy is so important that 'per capita energy consumption' has been recognised as one of the parameters to measure the extent of socio-economic development of a country. Fig. 2 provides the plot of this parameter for a large number of countries including India. Both in terms of social progress and per capita energy consumption, our country is placed quite low, particularly when compared with the so called developed countries. The ever-increasing demand of energy for the desired socio-economic development has given rise to a different type of challenges to the scientist and technologists.

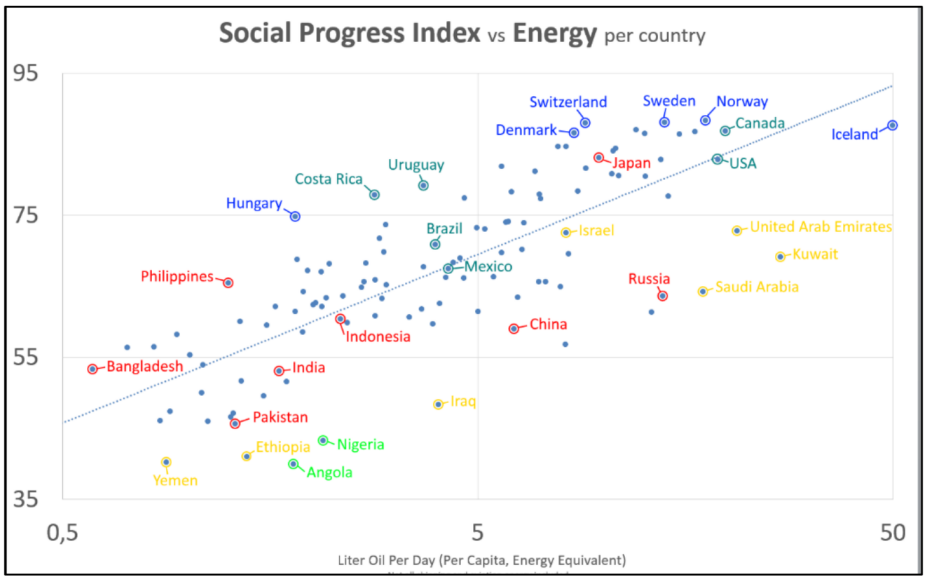


Fig. 2: Social progress index against per capita energy consumption for different countries [2].

The source of fossil fuel is not unlimited and is depleting at a dangerously high rate [3]. Therefore, alternative sources of energy must be identified and the necessary technologies have to be developed for harnessing them in an economic manner. This particular activity has been going on for the last several decades and has led to the development of a number of alternatives known as the "Renewable Energy" sources. As the name suggests these energy sources are either non-ending or continuously renewed through natural processes. For example, solar, wind and wave energies appear to be non-ending as long as human civilization exists on this planet. In addition there are other strategies to reduce the consumption of fossil fuels by increasing the energy conversion efficiencies of the existing technologies based on fossil fuels. This leads to less fuel consumption for the generation of same amount of energy and thereby saving the fuel for extended period of use. Another area where energy technologies are becoming more and more important is the environmentalconcern. All fossil fuels basically contain hydro-carbons and therefore produce significant amounts of greenhouse gas, CO_2 in particular, when burnt for the generation of usable form of energy. For this reason, uses of fossil fuels are more and more discouraged. Instead hydrogen gas, which produces non-polluting water vapour as the product of combustion, is slowly coming up as the preferred fuel of the future. This requires development of alternative technologies for cost effective generation of usable form of energy such as electricity. Automobile sector, which uses liquid fossil fuel (petrol / diesel), is one of the most polluting sectors and therefore extensive research and development are in progress for the development of electric vehicles either based on rechargeable battery or fuel cells using hydrogen as the fuel or supercapacitors, which is a device for storing large enough quantity of electrical energy.

All these developing technologies use different kinds of functional materials including ceramics and glasses, which will be discussed in details in the following sections.

By definition, ceramics are inorganic, non-metallic materials with relatively high melting points and therefore are useful for high temperature applications. From the chemistry point of view, they are composed of more than one element and may be oxides, carbides, nitrides, borides, silicides etc. Examples are Al_2O_3, SiO_2, ZrO_2, MgO, TiO_2,SiC, Si_3N_4, ZrB_2, $MoSi_2$etc. Chemical bonds are either totally ionic, or combination of ionic and covalent. Mixed cationic compounds e.g. $3Al_2O_3.2SiO_2$ (mullite), $BaO.TiO_2$ (barium titanate), $NiO.Fe_2O_3$ (Ni-ferrite), YBa2Cu3O7-δ (yttrium barium cuprate) etc. are also quite common. These wide range of compounds possess many exotic properties in terms of electrical, magnetic, mechanical, chemical and optical effects leading to many different unconventional applications. Several of them are non-stoichiometric in nature and give rise to interesting electrical and catalytic properties. These so called 'Advanced Ceramics' may be categorised as Electro-ceramics, Structural Ceramics, Electronic substrate and Packages, Ceramic Dielectric, Piezoelectric Ceramics, Magnetic Ceramics Conducting Ceramics Automotive Ceramics, Aerospace Ceramics, Wear Resistant Ceramics, Cutting Tools, Optical Ceramics, Bio-ceramics and so on. Many of them are essential components of the devices, which are important in the area of renewable energy [4].

Examples of a few technologies in which ceramics and glasses play important roles include

1) Different Types of Fuel Cell.
2) Rechargeable Batteries with high energy density.
3) Energy Harvesting
4) Clean Coal Technology.

2. The Fuel Cell

Fuel Cell is an electrochemical device which generates electrical power continuously as a gaseous fuel is electrochemically burnt (oxidised) in a continuous manner. Research and Development on fuel cells are going on over a century. There are a large number of Hand Books, Review articles and Reports published during this period. A few of them are mentioned here [5-11].

As in any electrochemical deviceit is constituted of an electrolyte, anode and cathode. The electrolyte may be either a liquid or solid having purely ionic conductivity, the anode and the cathode on the other hand are gaseous in character. However, there are solid current collectors with electronic conductivity on both anodic and cathodic sides. Important characteristics of a fuel cell are:

i) It generates electricity.
ii) Unlike a battery, which is also an electrochemical device, it requires a continuous flow of reactants.
iii) A fuel cell uses gaseous hydrogen or hydrocarbon as the fuel. The use of hydrocarbon, however, requires a reformer, which converts hydrocarbon to hydrogen.

Both for battery and fuel cell the electromotive force of the device is related to the thermodynamic free energy change for the overall chemical reaction between the anodic and cathodic materials used.

The overall electrochemical reaction occurring in a fuel cell using hydrogen and oxygen as the reactants may be described as:

$$H_2 \text{ (fuel)} + O_2/\text{ Air (oxidant)} \longrightarrow W + Q + H_2O \text{ (product)} \quad (1)$$

where W is the rate of electrical work done by the system and Q is the rate of heat transferred into the system from the surroundings at constant pressure and temperature.

Based on the thermodynamic principle, the E_{ocv}, the open circuit voltage of the cell may be expressed as

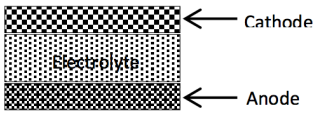
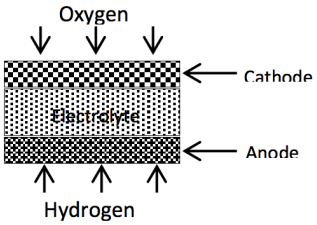
$$E_{ocv} = (RT/nF)\ ln\ P_{O2}(oxidant)/P_{O2}(Fuel) \quad (2)$$

This is known as the Nernst Equation in which R is gas constant, T is temperature, F is the Faraday constant, which is equal to 96,490 coulombs, 'n' is the number of electrons transferred during the reaction and P_{O2} refers to oxygen partial pressure. Based on the fact that the value of $n = 4$ for the above reaction (Eq. 1), the theoretical EMF of a fuel cell is controlled by the ratio of oxygen partial pressures of the fuel and the oxidant and its theoretical value under NTP condition is ~1.18 V and the theoretical conversion efficiency may be as high as 95% [12].

2.1 Fuel Cell and battery

The similarities and the differences between a battery and a fuel cell are listed in Table 1 below.

Table 1: Similarities and differences between Battery and Fuel Cell

Battery	Fuel Cell
	
Generate power electrochemically	Generate power electrochemically
Electrodes are the working materials	Gases are the working materials, Cathode and anode are current collectors
Electrodes get consumed	Electrodes do not get consumed
Limited period operation as long as the cathode and anode are available	Continue to operate as long as fuel gas and oxidant are supplied
Storage device	Conversion device

2.2. Heat Engine vs Fuel Cell

Coal is known to be the major fuel for generation of electricity particularly through thermal power plants (Fig. 1). Heat engine, which follows the Carnot's cycle, is the principle used in these plants. The efficiency of converting the chemical energy of the fuel to electricity is only of the order of 30-35%. Rest of the energy is wasted at different steps as the conversion is not direct but there are at least three steps namely: (i) chemical to thermal, (ii) thermal to mechanical, and (iii) mechanical to electrical as shown in Fig. 3 (below).

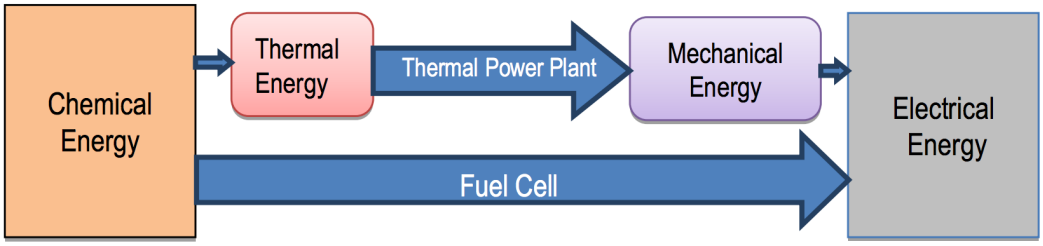


Fig. 3: Energy conversion steps in Thermal Power Plants and fuel cells.

Fuel cell, in comparison, is a single step process of converting chemical energy to electrical energy and therefore gives rise to very high plant efficiency of 60-65%. In addition to higher conversion efficiency, other advantages of the fuel cell are: (i) zero emission; both particulate and CO_2, (ii) no noise pollution, (iii) much less footprint, and (iv) an enabling technology acting as a technology platform which can promote several other related technologies.

2.3 Types of Fuel Cell and their Conversion Efficiency

There are at least six different types of fuel cell depending on the specific electrolyte and their operating temperature, which may vary from room temperature to 800°C [5]. The electrolytes may be either KOH (Alkaline Fuel Cell) or phosphoric acid solution (Phosphoric Acid Fuel Cell). However, one of the most useful one is Polymer Exchange Membrane Fuel Cell (PEMFC), in which a specific polymer (NAFION) having high proton conductivity is used as the electrolyte. This operates at a temperature of 80-100°C and isthe most attractive fuel cell for use in transportation (automobiles) sector. Other types of fuel cell are Molten Carbonate Fuel Cell (MCFC) operating at ~700°C in which CO_3^{2-} ion is the conducting species and finally the Solid Oxide Fuel Cell (SOFC), which uses a high temperature oxide namely Yttria Stabilized Zirconia (YSZ) with significant oxygen ion conductivity as the electrolyte [13-15]. This is an all ceramic fuel cell with highest possible conversion efficiency among all the different fuel cellsas well as other forms of power generating systems(Fig. 4). It operates at around 800°C and is suitable for stationary applications as distributed power plants. Originally it used to be operated at around 1000°C due to relatively low ionic conductivity of the electrolyte [16,17]. Currently it has been brought down to ~800°C through several innovative processing techniques particularly to reduce the electrolyte thickness. Of course, attempts are still being made to reduce the operating temperaturefurther [18].

It may be noted that Fuel cells have the highest energy conversion efficiency (40-65%) depending on the type and capacity, when SOFC is combined with a gas turbine, not only the plant capacity is enhanced but the efficiency may be increased to more than 70%. Incidentally, a gas turbine can be combined only with SOFC, because it operates at a high temperature and therefore the exhaust gas temperature is also high, suitable for operating a micro gas turbine. This possibility does not exist with any other type of fuel cell. Another very interesting characteristic of SOFC is that it can be operated with a very wide range of capacities, a few kilowatts to a few hundred kilowatts. Accordingly, SOFC plants are quite suitable as distributed power sources and can be deployed at the points of use. No transmission line would be required. Thermal power plants are economical only above hundred MW.

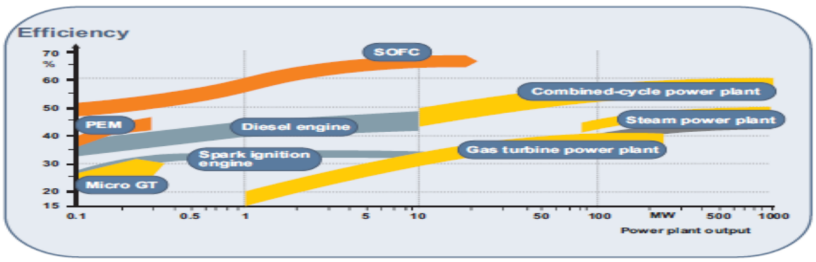


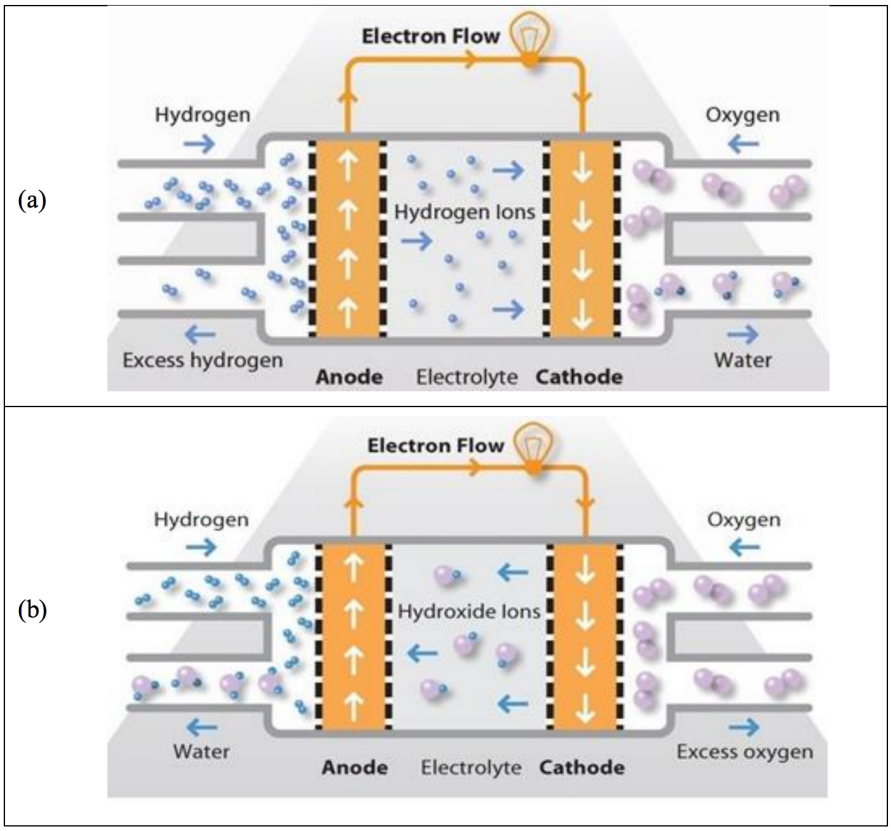
Fig.4: Efficiencies vs plant capacity for different types of power generating systems including fuel cells of two types (PEMFC and SOFC) [19].

2.4 Working Principle of Different Types of Fuel Cell

The working principles of four important types of fuel cell are presented in Fig. 5 [20]. It may be noted that in all these cases hydrogen gas is the fuel and oxygen is the oxidant. As mentioned earlier, alkali fuel cell uses a liquid electrolyte (KOH solution) with OH^- ion mobility operating in the temperature range 70-100ºC, PEM fuel cell uses solid polymer electrolyte with H^+ (proton) ion conduction with an operating temperature of 80-120ºC, molten carbonate fuel cell (MCFC) operates at a temperature 650-700ºC using a molten carbonate (eutectic mixture of lithium and potassium carbonates) electrolyte with CO_3^{2-} ion mobility and finally Solid Oxide Fuel Cell, which is an all ceramic fuel cell and on which our further discussion will follow, uses a high temperature resistant ceramic electrolyte namely Yttria Stabilized Zirconia (YSZ electrolyte with O^{2-} ion conduction.

2.5 Solid Oxide Fuel Cell

Our focus in this article is on Solid Oxide fuel Cell, all the components of which are either ceramics or glass. Extensive R&D has taken place over the last 50 years on this fuel cell and several hundred research and review papers have been published. A few representative ones are listed here [16,17,21-31]. The most common materials used in this fuel cell are:



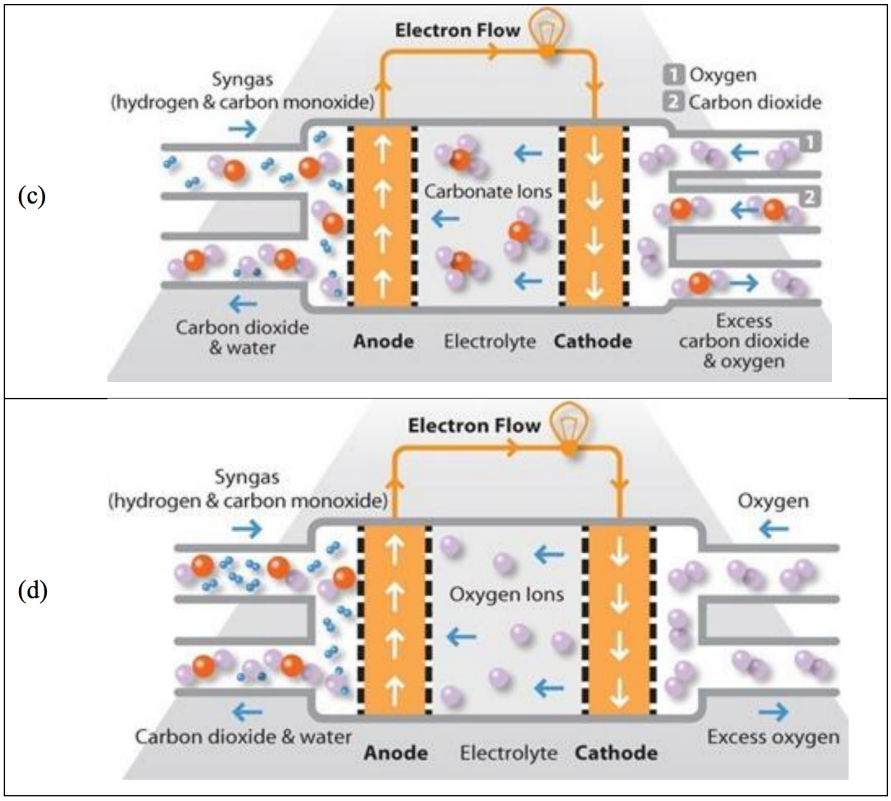


Fig.5: Pictorial representation of the working principle of four important types of fuel cell: Alkaline fuel cell (a), Polymer electrolyte membrane fuel cell (b), Molten carbonate fuel cell (c), and Solid oxide fuel cell (d) [20].

i) Electrolyte: 9mole% Y_2O_3 stabilised ZrO_2 (9YSZ)

ii) Cathodic current collector: $La_x Sr_{1-x}MnO_3$ (LSM)

iii) Anodic current collector: Ni-8YSZ Cermet

The present author and his group have carried out extensive research on the powder synthesis, sintering, microstructure development and related properties of the above materials [32-40]. A few years back Badwal and Foger made a comprehensive review of the emerging technologies and related materials in the area of energy conversion and storage [41]. Various other researchers together with this author's group have studied different alternative materials as well. This will be discussed later.

2.5 Design of SOFC

2.5.1 Material Selection

The basic concept of constructing a Solid Oxide Fuel Cell is to separate the fuel and oxidant compartments with a dense (non-porous) ceramic electrolyte, the most common is yttria stabilized zirconia (YSZ), which is known to be an excellent oxygen ion conductor. On the cathode side oxygen molecules when come in contact with the electrolyte gets ionized producing oxygen ion and migrates towards the anode side through the electrolyte. Similarly on the anode side when hydrogen gas comes in contact with the electrolyte gets ionized into hydrogen ion and reacts with oxygen ion migrating from the other side resulting into the formation of water vapour. Under any circumstances oxygen and hydrogen gases should not come in direct contact with each other to avoid possible explosion. The electrons to be supplied in the cathode side or to be

extracted from the anode side for ionization of the respective gases are performed by two electronically conducting ceramics which are also designated as current collectors. The cathodic current collector which is in contact with oxygen needs to be an oxide so that it does not get further oxidised during use. The anodic material which is in contact with a highly reducing gas like hydrogen cannot be a simple oxide, which may get reduced by hydrogen. The material also needs to be electronically conducting. The best choice for the purpose is a cermet (composite material) of metallic nickel and YSZ, which is stable even in the presence of hydrogen. Since the complete system (combination of all the three materials) has to perform at high temperature, it is essential that their thermal expansion coefficients are comparable to each other. This is certainly not an easy situation to achieve.Summary of the property requirements of all the components are presented in Table 2, which includes three additional components e.g. interconnect, glass seal and interlayer, the purposes of which are discussed later.

2.5.2 Construction

There are two basic designs of SOFC as presented in Fig. 6: (i) Tubular and (ii) Flat plate or planardesign. In the former design, a tube like configuration having a multilayer wall structure consisting of the electrolyte and the two electrodes is fabricated. The inner wall is made of the cathode material and is having a larger thickness to support the rest of the layers which are only a few microns in thickness. In addition, there is a thin strip of interconnect material, which is electronically conducting and do not chemically react with any of the other three materials. The purpose of this interconnect is to connect cathode of one cell (tube) to the anode of the next cell, which is stacked over the first tube (cell). In an actual plant, a large number of such tubes (up to 2 meters long) are stacked both side wise and vertically so that each cell is connected both in series and parallel to get higher voltage as well as draw large current from the stack. Such a stacking is necessary because each cell can generate less than 1 Volt (~ 0.7 V). This particular design was originally developed by Westinghouse, USA and later it was transferred to Siemens, Germany. They fabricated a large number of prototype units with a maximum capacity of 250 kW and demonstrated at different parts of the world using hydrogen as well as natural gas as the fuel. Unfortunately, it could not achieve the required cost effectiveness and therefore the particular design is discontinued. One of the great advantages of this design is that the oxidant and fuel compartments are easily separated; one flows through the inner core of the tube and the other flows through the outside.

Major developmental work has now shifted to planer design in which all the components are in the form of flat plates or sheets except the inter-connect, which is relatively thick and is grooved on both sides allowing the flow of fuel and oxidant (either oxygen or air). It may be noted that the grooves on either side are at right angle to each other for better connectivity to the external pipeline without the possibility of mixing with each other.

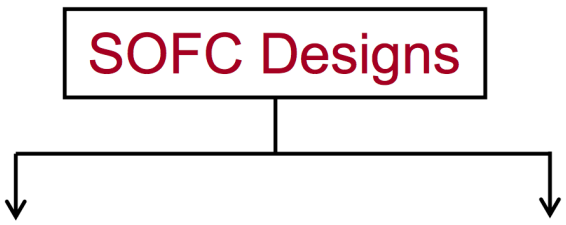
Table 2: Summary of the property requirements for different components of SOFC

Sl. No.	Functional Layer	Property Requirements
1.	Electrolyte	i) Purely ionic conductor. Sufficient conductivity at the operating temperature. ii) Full densification without any pore iii) As thin as possible to reduce internal resistance iv) Chemical stability in contact with both oxidizing and reducing atmospheres. v) Thermal expansion coefficient comparable with other components.

2.	Cathode	i) Purely electronic conductivity ii) Porous structure iii) Chemical stability in contact with the electrolyte and in highly oxidizing atmosphere. iv) Thermal expansion coefficient must be comparable with other components.
3.	Anode	i) Mostly electronic conductor with small amounts of ionic conductivity. ii) Porous structure. iii) Chemical stability in contact with the electrolyte and in highly reducing atmosphere. iv) Thermal expansion coefficient must be comparable with other components.
4.	Interconnect	i) Purely electronic conductivity ii) Fully Dense iii) Grooved on both sides in perpendicular directions. iv) Thermal expansion coefficient must be comparable with other components
5.	Glass Seal	i) Electrically insulating. ii) A glassy material with relatively high softening point. iii) Should get partially crystalized during cooling iv) Capable of thermal cycling v) Thermal expansion coefficient must be comparable with other components
6.	Interlayer	i) Electronically conducting ii) Should have nano-porous structure. iii) Chemically stable in contact with electrolyte and the electrodes.

The planar design may be constructed in different ways. Two of them are shown here. In the first case the thickness of the electrolyte is more than either the cathode or the anode. This is known as the 'electrolyte supported'. In the second case, which is currently more popular than the others, the thickness of the anode is greater than the other two. There are different techniques for fabrication of these layers. Thicker layers are fabricated by calendaring (rolling) or multilayer tape casting followed by sintering. Thinner layers are normally deposited by screen printing or plasma spray or sputter coating.

.



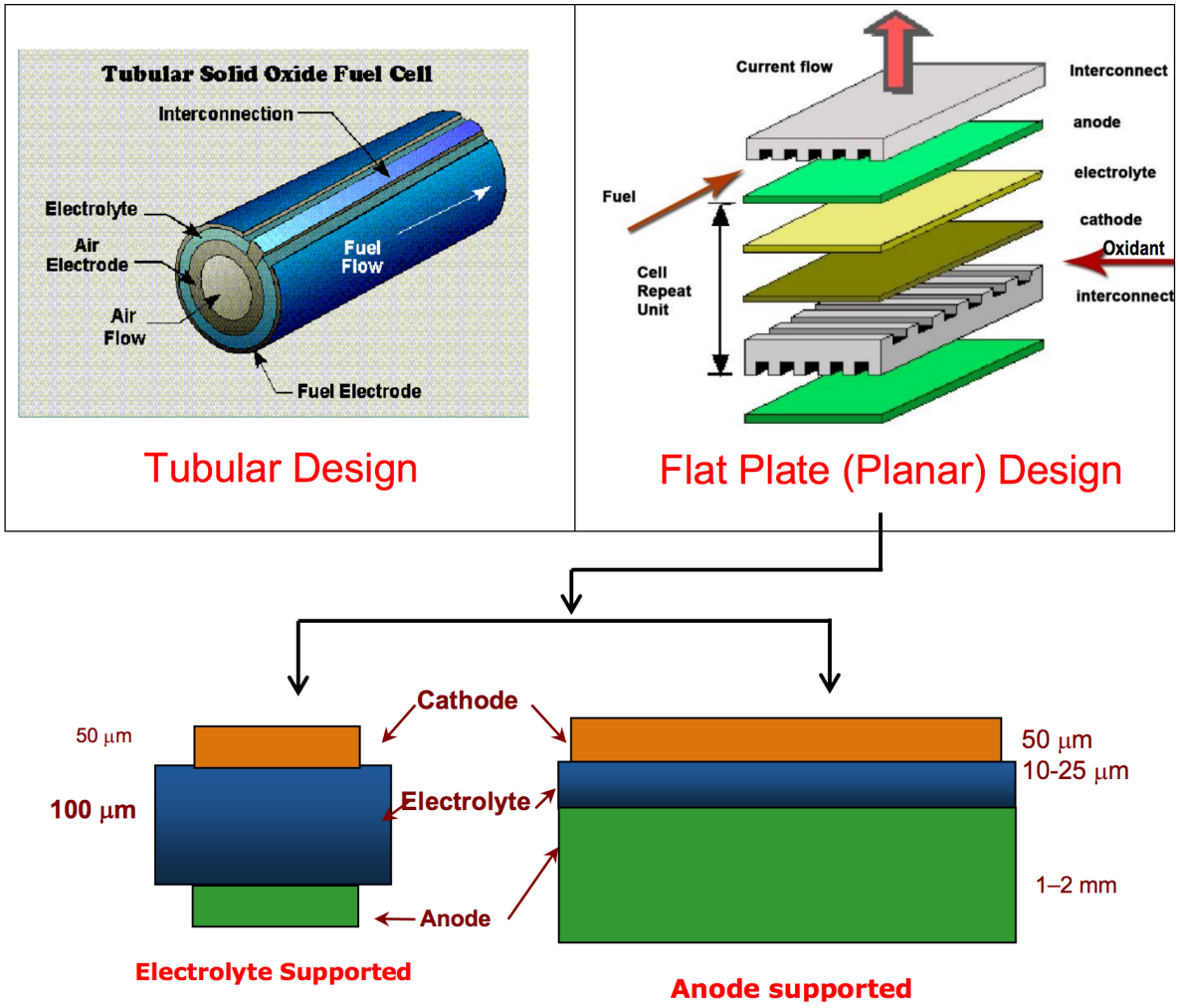


Figure 6: Different designs of SOFC [Adapted from Refs. 42&43]

2.6 Details of single cells of planar configuration

An exaggerated view of the cross section of a single unit (cell) of planer SOFC is presented in Fig. 7. The most important component is obviously the YSZ electrolyte layer (yellow in color). This is an oxygen ion conducting material; the direction of their movement is shown by the arrows (from cathode to anode). This layer is normally quite thin; of the order of 10-20μ and is fully dense (pore free). Oxygen movement takes place through lattice migration. No molecular diffusion of the gases are allowed, which may lead to explosion. On the anode side the reactions involved with both type of fuels namely hydrogen and carbon monoxide have been shown as this is the only type of fuel cell in which both these gases can be used as the fuel. Both cathode and anode layers are porous in nature so that the gaseous oxygen and hydrogen cancome in contact with the electrolyte layer. In fact it is the triple point contacts (electrolyte, porous cathode or anode and the gaseous oxidant or fuel gas) where electron transfers take place; either oxygen atom is ionized to oxygen ion (at the cathode) or oxygen ion releases its electrons to be captured by the anode. These electrons flow through the external circuit giving rise to electrical current. Thinner is the electrolyte layer, lower is the internal resistance of the cell facilitating drawing of higher current in the external circuit. In addition to the three layers mentioned

above, one more layer of grooved interconnect (Fig. 6) is also essential for making a series connection of the individual cells.

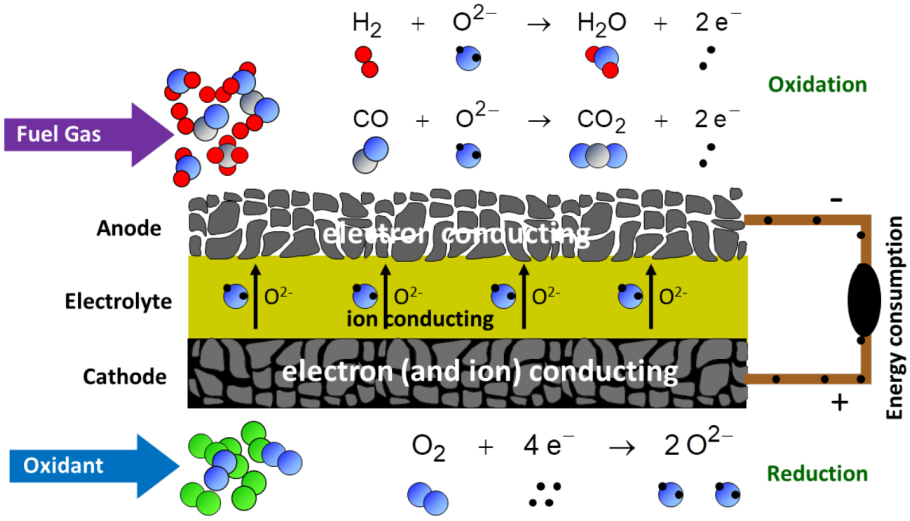


Fig. 7: Cross-section of a single unit of planar SOFC

The planar design also requires a fifth material which has not been shown in Figs. 6 & 7. That is a sealing glass, a thin layer of which is placed at all the four boundaries of the interconnect (both sides) to avoid the leakage of the gases, the fuel and the oxidant so that they do not come in direct contact with each other. Some researchers have also used nano-structured very thin layers, known as inter-layers between the electrolyte and the cathode or the anode in order to enhance the current density of the cells by way of increasing the number of triple points.

Photographs of a few single cells (looking like thin plates of multi-layer ceramics) with an area of 2" x 2" are presented in Fig. 8. In actual power stacks consisting of single cells of larger size of 4" x 4" are preferred. Several of these unit cells (50-100Nos.) are stacked one over the other with intermediate interconnect layer to develop power units of 5-10 kW. A typical microstructure of the cross-section of a single unit cell is presented in Fig. 9. Inclusion of an interlayer with a thickness of around 10µm is also seen in the picture.

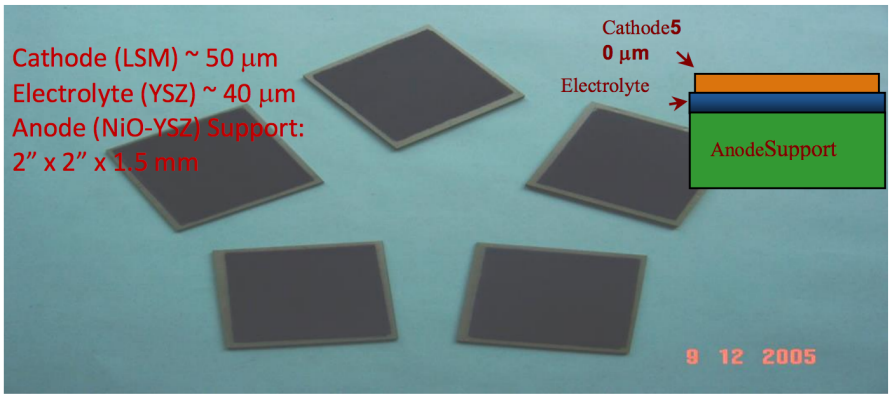


Fig.8: Typical anode supported planar SOFC single cells consisting of sintered three layer structure as shown in the top right hand corner. Typical thickness is 1.5-2.0 mm. These plates are often referred to as Membrane Electrode Assembly (MEA). Here the electrolyte is called the membrane because it preferentially allows only O^{2-} ions to pass through. (*Courtesy*: Fuel Cell and battery division, CSIR-CGCRI, Kolkata)

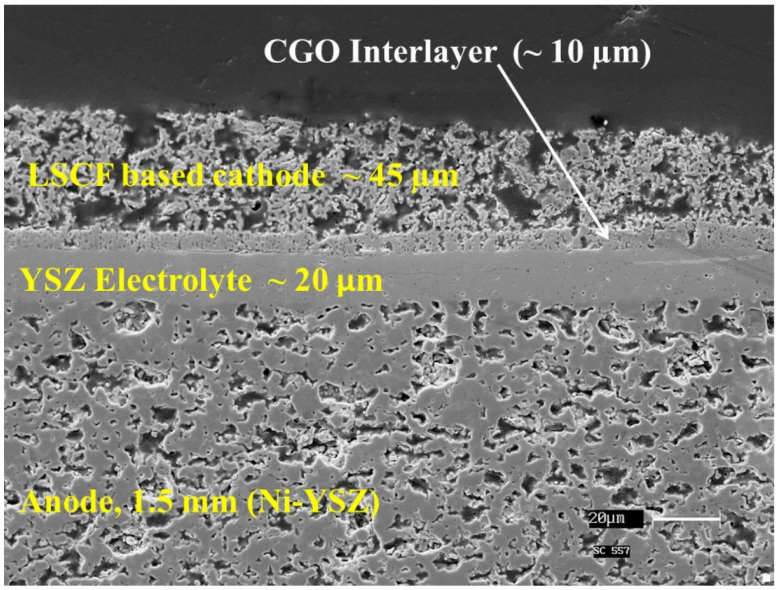


Fig.9: Microstructure of the cross-section of an SOFC Unit cell. Dense structure of the electrolyte and the porous structure of the electrodes are evident. This is an anode supported cell for which anode thickness is of the order of 1.5mm; thickness of the electrolyte is ~20µm; cathode is around 45µm. The cathodic interlayer is ~10µm with finer pores. CGO stands for Gadolinium doped cerium oxide (ceria) (*Courtesy*: Fuel Cell and battery division, CSIR-CGCRI, Kolkata)

2.7 Different alternative materials being tried for SOFC

In addition to the most common materials, e.g. YSZ (electrolyte) LSM (cathode) and NI-YSZ (anode), researchers have experimented with a large variety of alternative materials, a few of which are listed in Table 3.

Table 3: Alternative ceramics and glasses used for fabrication of SOFC [Compiled from the data presented in references 44 – 53]

	Electrolyte	Cathode	Anode	Interconnect	Composites of Glass Seals (mole%)
Most popular	9m/o YSZ	La (Sr)MnO_3 (LSM)	Ni-YSZ Cermet	Ferritic Steel	35BaO, 15CaO, 5Al_2O_3, 37SiO_2, 8B_2O_3
Alternative Materials	Gd – CeO_2 (GDC) Sc stabilized ZrO2 (ScSz) Sr – Mg doped La-Gallate(LSGM) La2Mo2O9	La-Co ferrite (LCF) (La,Co)FeO_4 (LCF) (LaSr)$CoFe_2O_4$ (LSCF) (BaSr)$CoFeO_4$ (BSCF) (La, Sr)Co03	Ni-Gd_2O_3 doped CeO_2 (CGO/ GDC) Gd_3O_3,Sm_2O_3 or Y_2O_3 doped CeO_2	Stainless Steel During the initial stages of development $LaCrO_3$ (LaCa)CrO_3 was used	35BaO, 5 La_2O_3 10Al_2O_3, 33SiO_2, 17B_2O_3 45BaO, 5Al_2O_3, 50SiO_2 25SrO, 20La_2O_3, 7 Al_2O_3, 40 B_2O_3, 8 SiO_2

3. Direct Carbon Fuel Cell

During the last few years, particular attention has been focused on this type Fuel cell in which solid carbon is used as the fuel which has several important advantages. Firstly, the energy released from the electrochemical oxidation of carbon to CO_2 by oxygen (23.95kWh/l) far exceeds that of most other non-solid fuels (e.g. hydrogen, methane etc.). Secondly, from thermodynamic consideration, the entropy change for carbon oxidation is zero and therefore from the theoretical energy conversion efficiency (η) is unity. This can be explained in the following way:

In terms of "2nd law" of thermodynamics the energy conversion efficiency (η) is defined as the ratio between of free energy (ΔG, the maximum energy that can be converted to electrical energy) and enthalpy (ΔH, the total chemical energy stored in the fuel).

$$\eta = \Delta G/\Delta H = (\Delta H - T\Delta S)/\Delta H$$

Now, for the reaction, $C+O_2 \rightarrow CO_2$, at 600 °C, $\Delta S \sim 0$ and $\Delta G = -395.4$ kJ/mol

ΔS being "zero" for carbon oxidation, $\eta = 1$. So, theoretically it becomes 100% efficient whereas, for oxidation of H_2 this value is only 76% and that of CO is only 66%. Again, if we can ensure compete combustion, CO production can be avoided. Moreover, as the fuel and exhaust gases are in different phases, there is less mixing between them. So, fuel utilization factor is also close to1 [54]. A schematic configuration of such a fuel cell is presented in Fig. 10 [55].

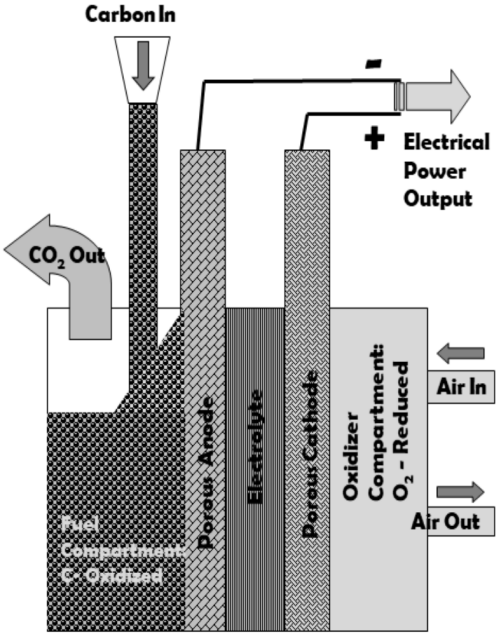


Fig.10: Schematic design of a Direct Carbon Fuel Cell (DCFC) [55]

In this case one uses a composite electrolyte, which is a mixture of YSZ and an eutectic mixture of alkali carbonates; either Na- and K- carbonate or Li-and Na-carbonate giving rise to a mixed ion electrolyte YSZ provides O^{2-} ion conductivity and the carbonate mixture provides $CO3^{-}$ conductivity. Both are required for the oxidation of solid carbon.

4. Energy storage devices

The most well-known storage device or in other words rechargeable battery is the lead-acid battery, which is used extensively in automobiles, inverters and for many other purposes. In addition, there is Ni-Cd, Ni-Metal hydride and of course the lithium ion battery, the heart of mobile phones laptops, cameras, watches etc. Comparison of their storing capacities is presented in Fig. 11 [56]. It is interesting to note that from the points of view of both weight and volume lithium ion battery has the largest specific capacity. Its open circuit voltage is also the highest. Let us discuss this system in alittle more details.

4.1 Lithium Ion Battery

4.1.1 Working Principle and Functional Materials:

i) Both anode and cathode are Lithium intercalated materials with sufficient Electronic Conductivity.

ii) Anode: Lithium intercalated graphite (LiC_6)

iii) Cathode: Lithium intercalated $LiCoO_2$ (Li_xCoO_2)

iv) Electrolyte (Liquid): Alkyl Carbonate + $LiPF_6$ [Solution of $LiPF_6$ in a mixture of Ethylene Carbonate and Di methyl Carbonate (EC-DMC) filled in a porous membrane called separator]

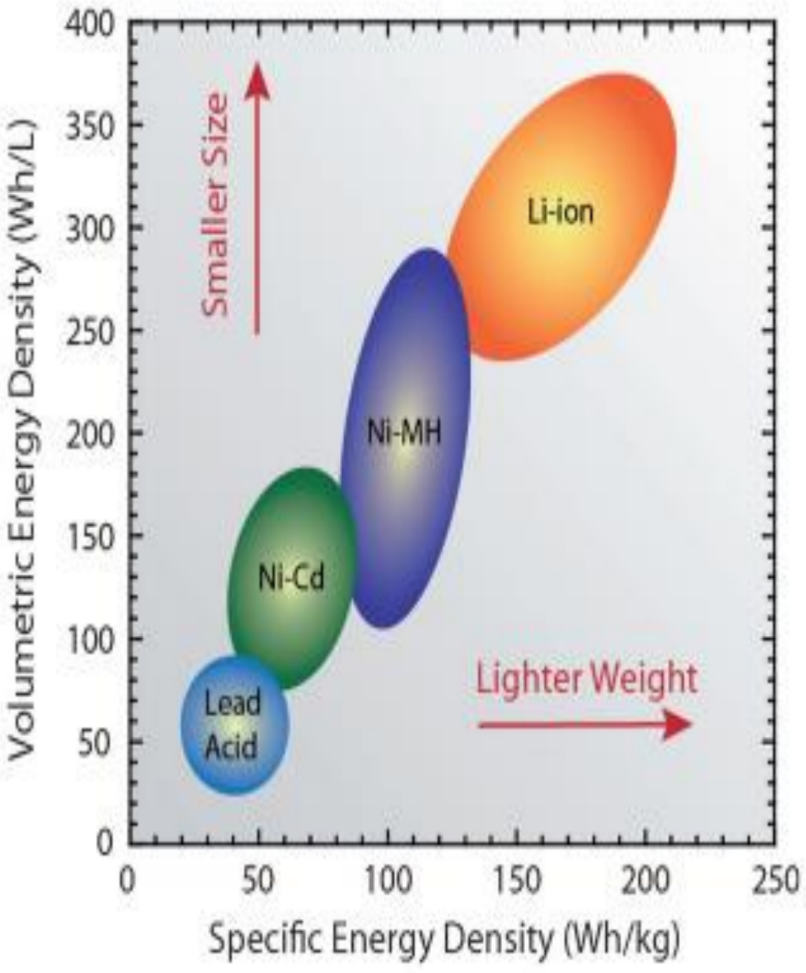


Fig. 11: Energy storing capacities of different rechargeable batteries [56].

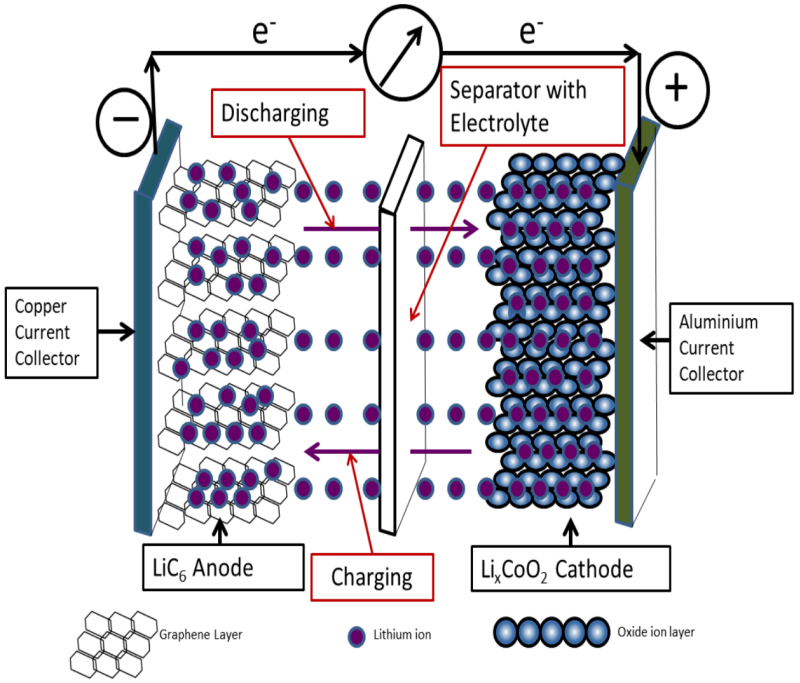


Fig. 12: Expanded View of Lithium Ion Battery Assembly

Atomistic movement of the lithium ion during charging and discharging cycles are explained in Fig.12. The chemical reactions are as follows:

(i) Discharging Process (Spontaneous)

Anodic reaction: $Li_xC_6 \rightarrow$ Graphite $+ Li^+ + e^-$

Cathodic reaction: $CoO_2 + xLi + xe^- \rightarrow Li_xCoO_2$ $(Co^{4+} \rightarrow Co^{3+})$

(ii) Charging Process (Non-Spontaneous)

Anodic reaction: Graphite $+ xLi^+ + xe^- \rightarrow Li_xC_6$

Cathodic reaction: $Li_xCoO_2 \rightarrow CoO_2 + xLi + xe^-$ $(Co^{3+} \rightarrow Co^{4+})$

(iii) *Overall Chemical Reaction:* $yC + LiMO_2 \rightleftharpoons Li_x C_y + Li_{(1-x)} MO_2$

where x is of the order of 0.5; $y = 6$ and $E_{ocv} = 3.7$ V

Even though Li_xCoO_2 is currently themost common cathode materials used today, it has a few disadvantages as follows: (i) Transformation of rhombohedral to monoclinic structure after repeated charge-discharge cycles. Accordingly, only 50% of theoretical capacity is realized, (ii) There are only a few sources of cobalt in the world and consequently the cost is exorbitant, and (iii) The oxide is not fully compatible with the organic electrolyte.

Researchers therefore are on the lookout for alternative materials not based on cobalt oxide. The potential of some of them are presented in Fig.13, which also includes some alternative anode materials replacing the well-known LiC_6. One may notice that several of the tetra-valent metals can replace graphite as the anode material.

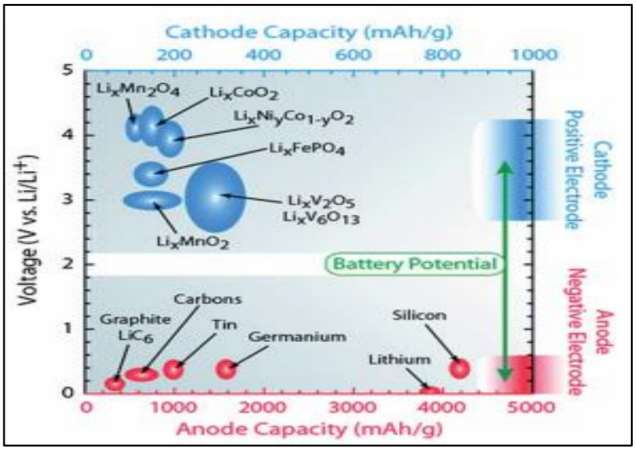


Fig. 13: Electrochemical data of a few alternative cathode and anode materials [57].

Among the alternative cathode materials, $Li_xMn_2O_4$ and Li_xFePO_4 are quite promising from practical point of view. In addition to the low power devices mentioned earlier, serious attempts are being made to use large size lithium ion batteries for the development of electric vehicles replacing low energy density lead-acid batteries. There cost is an important issue and therefore $LiFePO_4$ is being thought of as a potential cathode material for which prototypes are already available. Importance of nano-scale architecture for cathode materials has been demonstrated by several workers. The subject has recently been reviewed by Chen et al. [58]

4.2 Sodium-Sulphur Battery

In addition to lithium ion battery, sodium-sulphur battery is also a rechargeable-cum-storage battery, which is under development as a stationery power source. The electrolyte in this case is a high ceramics known as β"-alumina with chemical composition $Na_2O.11Al_2O_3$ with Na^+ ion conductivity. The electrolyte is used in the form of a one end closed tube as shown in Fig. 14(a). Molten sodium metal is used as the anode and Na_2S_x as the cathode. Operating temperature is around 150°C. Photograph of a typical β"-alumina one end closed tube is shown in Fig. 14(b).

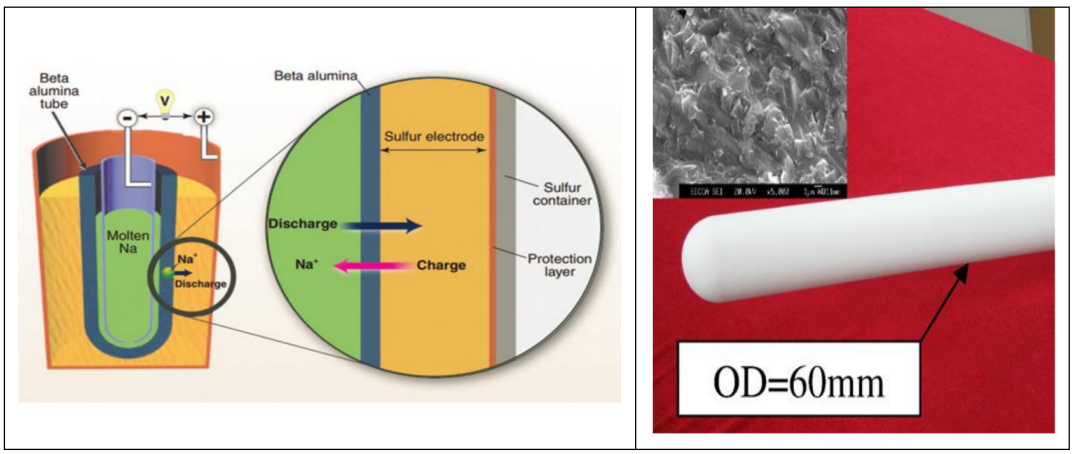


Figure 14: (a) Typical construction of a sodium-suphur battery [59], (b) Photograph of one β" Alumina [60]

Following are the reactions involved in these cells:

i) Anodic Reaction: $2Na = 2N^{+} + 2e^{-}$

ii) Cathodic Reaction: $xS + 2e^{-} = S_x^{2-}$

iii) Overall Reaction: $2Na + xS = Na_2S_x$

Prototypes of up to 50kW capacity have already been fabricated [60].

5. Energy Harvesting

The world is in the lookout for every possible way to generate and store additional energy from all kinds of unconventional sources even if the overall level of generation may not be very high. However, the advantage of harnessing such power may be useful at the local level particularly for running different electronic devices, which do not require very high level of power. Harnessing such small level of power in a distributed manner is normally known as "Energy Harvesting". The most important technique of energy harvesting is the use of piezoelectric transducer, which is capable of generating electricity from mechanical pressure or vibration.There are many areas where piezoelectric energy harvesting has been tried out.Examples are: vibration of bridges, vibration in the wings of an aircraft, vibration in helicopter rotor, pressure on the pavements and walkways, vibration in the gymnasium instruments, vibration in the railways, automobiles etc.

Piezoelectric effect has been known for a long time, however its exploitation in energy harvesting is relatively of recent origin. There are several piezoelectric materials, natural and synthetic known to us (Table 4). It may be noted that some of the natural and most of the synthetic materials may be regarded as "Ceramics".

Table 4: List of a few natural and Synthetic Piezoelectric Materials [61]

Natural	Synthetic
Quartz	Lead Zirconate Titanate (PZT)
Rochelle salt	Zinc Oxide (ZnO)
Topaz	Barium Titanate ($BaTiO_3$)
Sucrose	Gallium Orthophosphate ($GaPO_4$)
Silk	Potassium Niobate ($KNbO_3$)
Enamel	Lead Titanate ($PbTiO_3$)
	Lithium Tantalate ($LiTaO_3$)
	Langasite ($La_3Ga_5SiO_{14}$)
	Sodium Tungstate (Na_2WO_3)

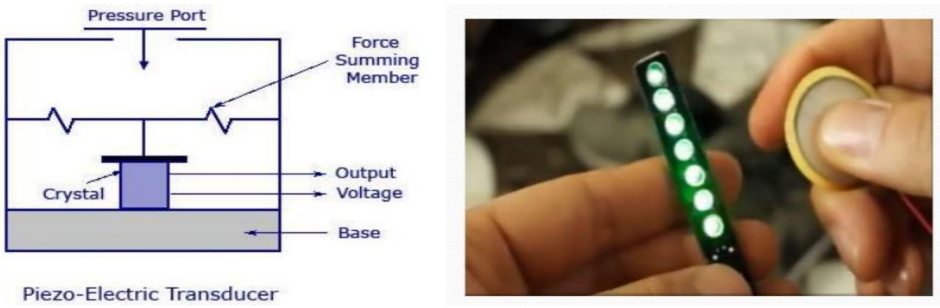


Fig. 15: Demonstration of energy harvesting with the help of piezo-transducer [61]

In above Fig. 15 demonstrates how piezo transducers can generate power through a simple arrangement (left) in order to illuminate a few LED bulbs (right). In this case the piezo-transducer is in the form of a disc is hand-held.

In order to enhance power generation, flexible piezoelectric strips made from electro-spun PZT ceramic fibres embedded in a polymer are used as shown in Fig. 16.

Fig. 16: Flexible Piezocomposites for energy harvesting [62]

6. Clean Coal Technology

While renewable energy technologies are in the developmental stage particularly to make them economically attractive, parallel efforts are being made how to make established technologies like the thermal power plants (based on coal) more efficient and environment friendly. In this context introduction of Integrated Gasification Combined Cycle (IGCC) technology utilizing different types of high temperature ceramics, is one such possibility. In this technology, coal, instead of simply burning in a boiler to generate steam, is first treated in a gasifier to generate syngas, from which particulates are separated with the help of the ceramic (porous silicon carbide) filter and part of hydrogen is separated with ion selective solid membrane and the purified gas is finally burnt to produce steam. Different uses of ceramics in IGCC may be summarized as follows:

- Oxygen enrichment of feed air to the gasifier through oxygen transport membrane (YSZ)
- Cleaning of syngas at a high temperature (~1000°C) and high pressure (~30bar) by porous silicon carbide tubular filters.
- Use of ion transport membrane for separation of hydrogen.
- Refractory lining in the gasifier.

By this process overall conversion efficiency increases and also the pollution remains under control. The technology is still under developmental stage.

In addition to above, abrasion resistance ceramics (sintered aluminium oxide in particular) is extensively exploited for lining of the internal surface of the large diameter steel pipes to carry the pulverized coal from the pulverizing plant to the boiler and also to transport burnt coal ash from the boiler to the dumping grounds. Other areas which use abrasion resistant ceramic tiles include different kinds of hoppers used in metallurgical and mineral processing plants. Besides sintered ceramics, some of these hoppers also use tiles prepared by melting

natural rocks like basalt. Such tiles may be termed as “glass ceramics” which is basically crystalline compounds dispersed in a glassy matrix.

7. Summary and Conclusions

It may easily be concluded from the above discussion that a variety of ceramics, glasses or glass-ceramics having important functional propertiesareplaying important roles in renewable energy technologies, in the areas of energy conversion and storage. They are also important for enhancing the conversion efficiency and suppress the environmental pollution of the existing thermal power plants based on coal. Piezo-electric ceramics are also plying important roles in harnessing energy from different types of vibrations experienced by us in our daily life and industrial activities.

Acknowledgement: The author gratefully acknowledges the research contribution made by his junior colleagues and students from IIT, Kharagpur, CSIR-CGCRI, Kolkata and GCECT, Kolkata, which have been included in this paper. He is also grateful to Dr. Saibal Ray, the Editor of this e-journal for his invitation to write this review paper.

References:

1. Wikipedia (https://en.wikipedia.org/wiki/World_energy_consumption).
2. Wikipedia (https://en.wikipedia.org/wiki/List_of_countries_by_energy_consumption_per_capita#/media/File:SpcialProgressIndexVsEnergInOilPerDay2.png).
3. E. Stephens, I.L. Ross, J.H. Mussgnug, L.D. Wagner, M.A. Borowitzka, C. Posten and O.K.B. Hankamer, *Trends in Plant Science* **15** (2010) 564.
4. J. Rödel, A.B.N. Kounga, M. Weissenberger-Eibl, D. Koch, A. Bierwisch, W. Rossner, M. J. Hoffmann, R. Danzer and G. Schneider, *J. European Ceram. Soc*. **29** (2009) 1549.
5. *Handbook of Fuel Cells: Fundamentals, Technology, Applications, 4 Volume Set eds.* W. Vielstich, A. Lamm, H.A. Gasteiger (John Wiley & Sons, 2003).
6. S.M. Haile, *Acta Materialia* **51** (2003) 5981.
7. *Fuel Cell Handbook (Seventh Edition) by* EG & G Technical Services, Inc., US Department of Energy (2004).
8. *Fuel Cells Compendium (compilation of 30 previously published papers) eds*. N.P. Brandon and D. Thompsett (Elsevier B.V. Amsterdam, 2005).
9. B. Sørensen, *Hydrogen and Fuel Cells* (Elsevier B.V. Amsterdam, 2005).
10. *Compendium of Hydrogen Energy, Part III,* eds. F. Barbir, A. Basile and T.N. Veziroglu (Woodhead Publishing Series, 2016).
11. R. O'Hayre, S.-W. Cha, W. Colella and F.B. Prinz, *Fuel Cell Fundamentals, 3rd Edition* (John Wiley & Sons, 2016).
12. LindiweKhotseng in *Thermodynamics and Energy Engineering* ed. P. Vizureanu (Intech Open Access, 2020).
13. E.C. Subbarao and H.S. Maiti, *Proc. Conf. on High Temp. Solid Oxide Electrolytes*, ed. F.J. Salzano; **1**(1983) 151 (Associated Universities Inc., New York).
14. E.C. Subbarao and H.S. Maiti, *Solid State Ionics* **11**(1984) 317.
15. P. Sengupta, A. Bhattacharjee and H.S. Maiti, *Trans. IIM* **72** (2019) 1981.
16. H. S. Maiti and M.K. Paria, *Sadhna* **13** (1988) 59.
17. P. Sujatha Devi, A. Das Sharma and H.S. Maiti, *Trans. Ind. Ceram. Soc*. **63 (**2004**)** 75.
18. B. Singh, S. Ghosh, S. Aich and B. Roy, *J. Power Sources* **339** (2017) 103.
19. K. Hassmann, *Fuel Cells* **1** (2001) 78.
20. Fuel Cell Today (www.fuelcelltoday.com).
21. B.C.S. Steele, *Ceram. Int.* **19** (1993) 269.
22. S.P.S. Badwal and K. Foger, *Ceram. Int.* **22**(1996) 257.
23. S.C. Singhal, *Solid State Ionics* **135** (2000) 305.
24. G. Cacciola, V. Antonucci and S. Freni, *J. Power Sources* **100** (2001) 67.

25. S.C. Singhal, *Solid State Ionics* **152** (2002) 405.
26. M.C. Williams, J.P. Strakey, W.A. Surdoval and L.C. Wilson, *Solid State Ionics* **177** (2006) 2039.
27. E. Ivers-Tiffee, A. Weber and D. Herbstritt, *J. Eur. Ceram. Soc*. **21** (2001) 1805.
28. A. Weber and E. Ivers-Tiffée, *J. Power Sources* **127** (2004) 273.
29. D. Stöver, H.P. Buchkremer and S. Uhlenbruck, *Ceram. Int.* **30** (2004) 1107.
30. R. Mückea, O. Büchlera, M. Brama, A. Leonideb, E. Ivers-Tiffée and H.P. Buchkremera, *J. Power Sources* **196** (2011) 9528.
31. M. Irshad, K. Siraj, R. Raza, A. Ali, P. Tiwari, B. Zhu, A. Rafique, A. Ali, M.K. Ullah and A. Usman, *Appl. Sci.***6 (2016)** 75.
32. A. Chakraborty, P. Sujatha Devi and H.S. Maiti, *Materials Letts.* **20** (1994) 63.
33. A. Chakraborty, P. Sujatha Devi and H.S. Maiti, J. *Mater Res.* **10** (1995) 918.
34. A. Chakraborty, R.N. Basu, M.K. Paria and H.S. Maiti, *Proc. Fourth Int. Symp. on Solid Oxide Fuel Cells,* eds. M. Dokiya, O. Yamamoto, H. tagania and S.C. Singhal (The Electrochemical Soc. Inc., USA, 1995).
35. R.N. Basu, S.K. Pratihar, M. Saha and H.S. Maiti, *Materials Letters*, **32** (1997) 217.
36. S.K. Pratihar, R.N. Basu and H.S. Maiti, *Trans. Ind. ceram. Soc* ,**56** (1997) 85.
37. A. Chakraborty and H.S. Maiti, *Ceram. Int***. 25** (1999) 115.
38. S.K. Pratihar, R.N. Basu, S. Mazumder and H.S. Maiti, *Solid Oxide Fuel cells (SOFC VI)***,** *Proc. Six Int. Symp.*, eds. S.C. Singhal and M. Dokiya (The Electrochemical Soc. Inc., 1999).
39. A. Chakraborty, R.N. Basu and H.S. Maiti, *Mats. Letts.* **45** (2000) 162.
40. A. Kumar, P. Sujatha Devi and H.S. Maiti, *Chem. Mater.* **16** (2004) 5562.
41. S.P.S. Badwal, S.S. Giddey, C. Munnings, A.I. Bhatt and A.F. Hollenkamp, *Frontiers in Chemistry / Chemical Engineering* **2** (2014) 1.
42. https://americanhistory.si.edu/fuelcells/so/sox1.htm.
43. https://www.artikel-presse.de/planar-solid-oxide-fuel-cell-sofc-market-global-analysis-and-forecast-2016-2020.html.
44. S. Basu, P. Sujatha Devi and H.S. Maiti, *J. Mater. Res.* **19** (2004) 3162.
45. S. Basu, P. Sujatha Devi and H.S. Maiti, *Appl. Phys. Letts***. 85** (2004) 3486.
46. A. Mai, V.A.C. Haanappel, S. Uhlenbruck, F. Tietz and D. Sto¨ver, *Solid State Ionics* **176** (2005) 1341.
47. S. Basu and H.S. Maiti, *J. Electrochem. Soc***. 156** (2009) 114.
48. S. Basu, P. Sujatha Devi, H.S. Maiti and N.R. Bandyopadhyay, *Solid State Ionics* **231** (2013) 87.
49. W. Zhou, R. Ran and Z. Shao, *J. Power Sources* **192** (2009) 231.
50. M.C. Tucker, *J. Power Sources* **195** (2010) 4570.
51. I. Aznam, A. Muchtar, M. Rao Somalu, M.J. Ghazali, J.C.W. Mah and N.A. Baharuddin, *J. Adv. Res. Fluid Mech. Thermal Sci.* **51** (2018) 227.
52. M. Mukhopadhyay, J. Mukhopadhyay and R.N. Basu, *Trans. Ind. Ceram. Soc.* **72** (2013) 145.
53. M. Suklueng, in *Adv. Glass Sci. Tech.,* Chap. 10 (Intech Open Access Book, 2018).
54. S. Giddey, S.P.S. Badwal, A. Kulkarni and C. Munnings, *Prog. Energy Combust. Sc.* **38** (2012) 360.
55. S. Basu, Md. N. Alam, S. Basu and H.S. Maiti, *J. Alloys Comp.* **816** (2020) 152561.
56. B.J. Landi, M.J. Ganter, C.D. Cress, R.A. DiLeo and R.P. Raffaelle, *Energy Environ. Sci*., **2** (2009) 638.
57. M. Osiak, H. Geaney, E. Armstrong and C. O'Dwyer, *J. Mater. Chem.* **2*A*** (2014) 9433.
58. R. Chen, T. Zhao, X. Zhang, L. Li and F. Wu, *Nanoscale Horiz.* **1** (2016) 423.
59. Z. Wen, J. Cao, Z. Gu, X. Xu, F. Zhang and Z. Lin, *Solid State Ionics* **179** (2008) 1697.
60. Y.-X. Wang, B. Zhang, W. Lai, Y. Xu, S.-L. Chou, H.-K. Liu and S.-X. Dou, *Adv. Energy Mater.* (2017) 1602829-1.
61. A.A. Khan, slide share (https://www.slideshare.net/iamaproudindian/44-azeem).
62. A. Majit, Slide Service (https://www.slideserve.com/wade-mcfarland/piezoelectric-energy-harvesting).

Scientific Voyage
Vol. 1, No. 3,
Page 21-26 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Jul.-Sep.

Bidhu Bhushan Ray: Interaction with Yoshio Nishina and Werner Heisenberg

Rajinder Singh
Research Group – Physics Didactic and Science Communication, Physics Institute, University of Oldenburg, 26111 Oldenburg, Germany; E-mail: *rajinder.singh@uni-oldenburg.de*

Abstract: Bidhu Bhushan Ray, unsung her of Indian science, did research under the Nobel Laureates Manne Siegbahn, Sweden, and Niels Bohr, Denmark. In contrast, the Japanese Yoshio Nishina is considered as the founding father of modern physics research in Japan. The German Werner Heisenberg was one of the founders of the quantum mechanics. With the help of their correspondence, in the present short communication, their interaction is explored.

1. Introduction

Bibhu Bhushan Ray (abb. BBR) was one of the pioneer of the X-ray spectroscopy in India [1]. He received the Elliot Prize for Science - Asiatic Society of Bengal; the Silver Medal - University of Calcutta; became a Premchand Roychand Scholar; and was awarded the Palit Foreign Scholarship, and the Mahendra Lal Sircar Research Gold Medal [2]. He was Fellow of the National Institute of Sciences of India (today known as Indian National Science Academy, INSA). To the best of my knowledge, "Bidhu Bhushan Ray - A Pioneer of X-Ray Spectroscopy" is the only biography, which deals with his life and science [3]. Unfortunately, the book is not available in India. The present article, based on various parts of the book, explores relation between B.B. Ray, Werner Heisenberg, and Yoshio Nishina.

To start with a summary of B.B. Ray's life is given.

Figure 1: Bidhu Bhushan Ray *[Credit: B.B. Ray' family members]*

2. Bidhu Bhushan Ray – A short Life History

Bidhubhusan Ray was born on July 1, 1894, in the village of Khandarpara in District Faridpur in East Bengal, now known as Bangladesh. His father, Basanta Kumar Ray was a postmaster, and his mother, Bamasunderi Devi, was a house-wife.

Bidhubhusan was only 14 when his father passed away at the age of 49. This led to a hard life for his wife and children. BBR passed the Matriculation Examination in 1911 with distinction, and graduated

with an Intermediate Science degree from Ravenshaw College. He did B.Sc. from Presidency College Calcutta in 1915, and in 1918, obtained M.Sc. degree from Calcutta University. Ray was offered a job in the Bengal Civil Service. He declined, because Sir Asutosh Mukherjee inspired him to pursue research.

B.B. Ray started his research career under C.V. Raman, Palit Professor, at the University of Calcutta. The Board of Examiners of the University of Calcutta appointed G.C. Simpson, J.W. Nicholson and E.H. Barton as the examiners to evaluate Ray's D.Sc. thesis. On 1st November, 1922, they submitted a report and stated that they examined Bidhubushan Ray's thesis. According to their opinion, it is "sufficient merit to warrant the conferment upon Mr. Bidhubushan Ray of the Doctorate." The thesis: "The scattering of light by liquid droplets and the theory of coronas, glories and iridescent clouds" deals with an interesting branch of meteorological optics. The results obtained by the candidate are new and valuable [4].

In 1922, BBR was appointed as Lecturer in Physics. In the beginning of 1923, for higher studies abroad, he was given Palit Travelling Scholarship for two years. He wrote to Niels Bohr on March 23, 1923, and expressed his desire to work in his Laboratory. With the letter, he sent the reprint of his already published paper in "Nature" of Feb. 10, 1923 [5]. Bohr suggested to postpone the visit to Copenhagen until January 1924, because he (Bohr) had planned a visit to the U.S.A. [6]. BBR decided to travel to Sweden for a short time and work with Manne Siegbahn, who was known for his experimental research on X-ray spectroscopy. BBR stayed for two and a half years in Europe, where he worked in Manne Siegbahn's laboratory in Uppsala, and at the newly founded Niels Bohr Institute in Copenhagen.

After returning back to Kolkata, he established a laboratory for x-ray spectroscopy. For a short time he was appointed Khaira Professor. On April 5, 1940 his term expired, but he was reappointed on permanent bases on a salary of Rs. 800 per month [7].

BBR married to Asha Sen (Fig. 2), daughter of Nishi Kanto Sen, Registrar, University of Delhi, who had contact with the great poet (Fig. 3). Asha Sen had an M.A. in English. Later she became a lecturer at Visva Bharati, Santiniketan, an institution founded by the great poet Rabindranath Tagore. Unfortunately, Asha Ray only had a short period of happily married life, as her husband died at the young age of 49. Their daughter, Uma Sen was brought up by her mother.

Figure 2: Ray's wife Asha Ray with her daughter Uma *[Credit: B.B. Ray's family]*

On Sept. 7, 1935, the great poet wrote to the father of BBR's wife: "I was rather unwell when your daughter's wedding card came. I could not send my blessing. Kindly excuse me. I shall be glad if the newly married couple can visit me. Then I shall bless them." [8]

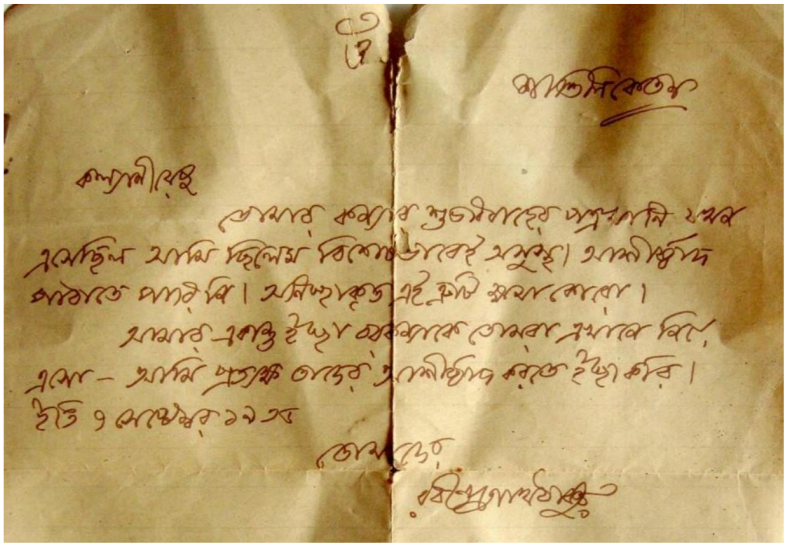


Figure 3: Rabindranath Tagore's handwritten letter *[Credit: B.B. Ray's family]*

BBR took his last breath in his home in Calcutta on July 29, 1944. His successor was the legendary S.N. Bose, who took over the X-ray laboratory and an active group of research workers [9].

3. Bidhubhusan Ray in Copenhagen

In Copenhagen Ray came in contact with Yoshio Nishima (Japan), Samuel Goudsmit (Holland), Ralph Fowler (England), Friedrich Hund (Germany) and others (Figure 4).

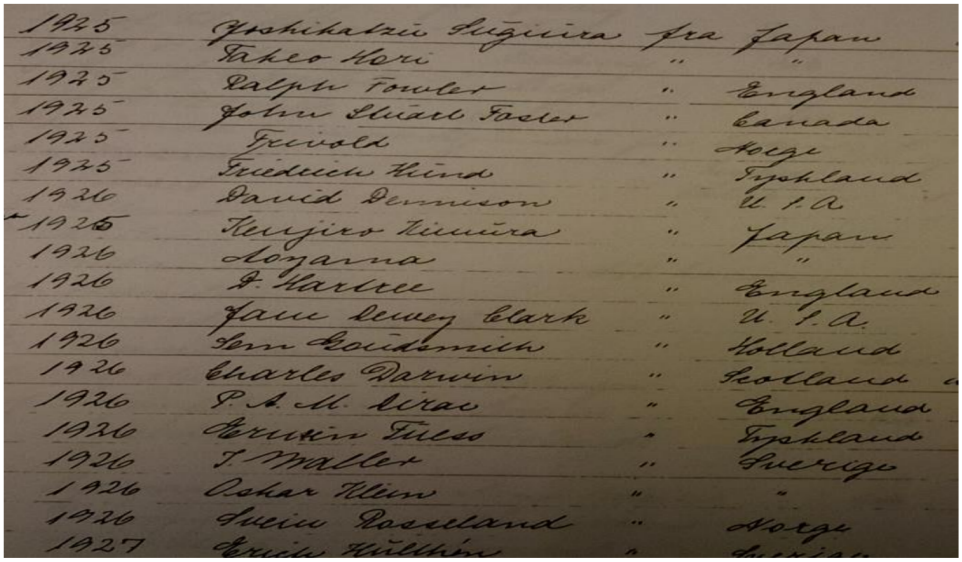


Figure 4: Some of the guest scholar's at Bohr Institute during B.B. Ray's stay *[Credit: Niels Bohr Archive, Copenhagen]*

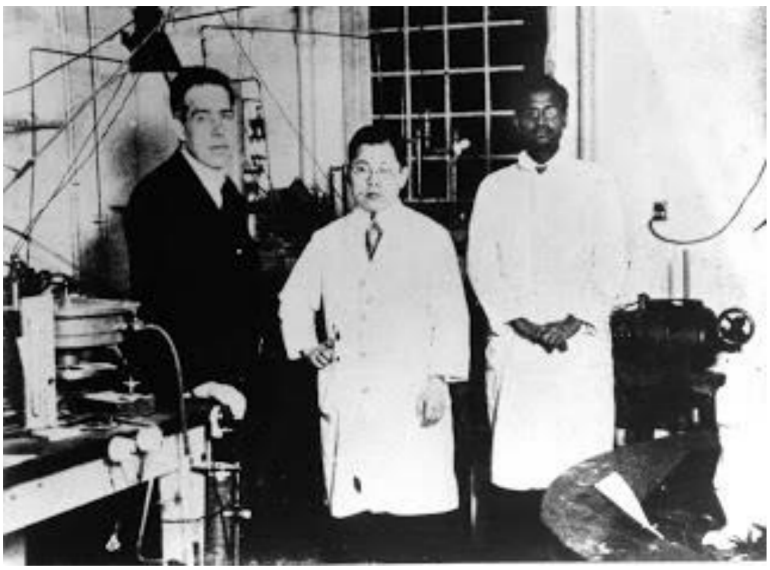


Figure 5: Niels Bohr, Yoshio Nishina and B.B. Ray *[Credit: Niels Bohr Archive, Copenhagen]*

4. Sharing political and private life

4.1 Politics

On Feb. 29, 1928, BBR wrote a long letter to Y. Nishina. In part it reads: "You know, I was once interested politics, and I did a little bit when I came back here, but I have found out that the politicians are as a rule scoundrels, and I have given it up as hopeless, and have returned to my laboratory, only to find it also a horrible mess" [10].

BBR had also written to N. Bohr that India is passing though bad time. Due to political activities, more than 50,000 persons are in prisons. "My house was searched and my younger brother & two cousins were arrested. After being detained for about a month & a half, they are all now released" [11], wrote Ray. He was not arrested. Obviously, he distanced himself from the active politics.

In 1929, Werner Heisenberg visited Japan and India. After returning to Germany, he informed about his impression of the Himalayas [12]. Later, Ray's younger brother, Shashi Bhusan Ray [13], went to Germany for higher studies, he met Heisenberg [14].

It is almost unknown to the political and scientific world that BBR had close contact with Netaji Subash Chandra Bose. There is rumour that due to BBR's contact with the physicist Werner Heisenberg, S.C. Bose met the German dictator Adolf Hitler. Netaji's contact with Ray are explored elsewhere [15].

4.2 *Private communication*

In the late 1920s, BBR was going through hard life. He had trouble with his heart. On Feb. 29, 1928, he wrote to Y. Nishina that he has consulted the both Europeans and Indian doctors; but without success for his health. Also, his mother, after suffering for a long time, was cured. His heart breaking letter continues: "Now for the last 3 or 4 months my only sister is suffering from Tuberculosis and I do not know whether she will recover at all." Then he told about his meagre salary, 30 Pounds per month. As even today, most of the young people think that the solution of their financial problem is to go abroad; so was BBR's case. He asked Y. Nishina to talk to N. Bohr and explore an opportunity for getting a scholarship abroad. Bohr indeed helped him. As we see from Fig. 6, Ray was in Bohr's laboratory again, for about a year.

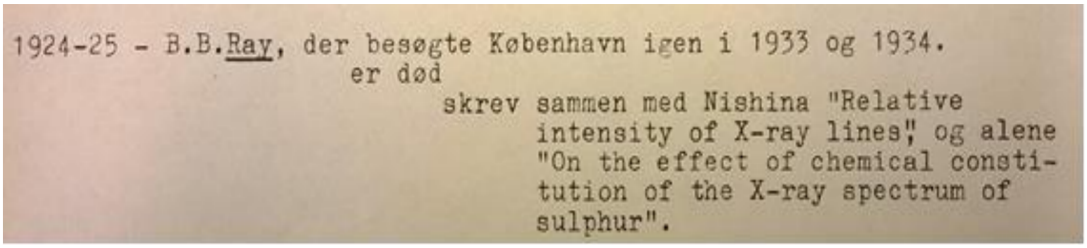

1924-25 - B.B.Ray, der besøgte København igen i 1933 og 1934.
er død
skrev sammen med Nishina "Relative intensity of X-ray lines", og alene "On the effect of chemical constitution of the X-ray spectrum of sulphur".

Figure 6: B.B. Ray stay time and research work at the Niels Bohr Institute *[Credit: Niels Bohr Archive, Copenhagen]*

As far as Ray's publications at the Bohr Institute are concerned, Nishina and Ray published a short article in "Nature" on the "Relative intensity of X-ray lines". Their results were not satisfactory. The authors promised to write more on the experimental detail and further measurements [16]. However, the work was not continued, as BBR left Copenhagen. He alone wrote paper, which was communicated by Bohr [17]. In the article, he (BBR) acknowledged: "Mr. Y. Nishina for his unfailing friendly help and interest during the work, and to Professor G. Hevesy [a future Nobel Laureate] for kindly supplying me with the sulphur compounds for this investigation" [17]. The relevance of the work can be judged by the fact that in the middle of the 1960s, A. Meisel in a review article referred to Ray's article 'The influence of the chemical bond on X-ray emission and absorption spectra" and other works [18].

5. Conclusions

B.B. Ray's life story could be an interesting example for younger generation, in particular for students with poor family background. Due to his passion for research, he decided for scientific career. Though, he lived short life, during this short period he became Editor of the renowned journal "Science and Culture". He was elected as the Fellow of the Indian National Science Academy (in those days Indian Institute of Sciences of India). After his death M.N. Saha established B.B. Ray Memorial Lecture under the title: 'Professor Bidhu Bhushan Ray Memorial Lectureship' on Experimental and Mathematical Physics and allied subjects. A Committee collected Rs. 8332 as fund. The ceremony of unveiling of the portrait of B.B. Ray was performed on January 28, 1946 before a gathering of colleagues, research workers, friends and admirers of Professor Ray in the Pure Chemistry Lecture Theatre [3].

Today neither his portrait nor his laboratory exists. The X-ray Laboratory made by him, was taken over by S.N. Bose. Today we know Bose's name better than Ray. Why so? The answer is very simple, namely, we Indians give too much importance to "discoveries" and "inventions", and entirely ignore the achievements of scientists like B.B. Ray who established a new field of science and technology. On the long run, such acts had more impact on the society than a "discovery".

Acknowledgements: First and the foremost, I thank Dr. Saibal Ray, Editor-in-Chief, *Scientific Voyage* for editorial work. Thanks are due to Professor B.B. Ray's nephews Mr. Subrata Roy, Prof. Debabrata Ray - The National Council of Education, Bengal, and daughter Dr. Uma Sen – Viswa Bharti for sharing family history and documents referred to here. I thank the Philosophical Archive, University of Konstanz; and Niels Bohr Archive, Copenhagen for documents referred to in this article. I thank Prof. Arnab Rai Choudhuri IISc, Bangalore for translating R. Tagore letter to N.K. Sen. Last but not the least, I am grateful to Prof. Dr. Michael Komorek, Research Group – Physics Didactic and Science Communication for providing me research facilities.

References:

1. M.S. Hegde, Book Review - X-Ray Spectroscopy and Allied Areas. S.K. Joshi, B.D. Shrivastava and A.D. Deshpande (Eds). Narosa Publishing House, 6 Community Centre, Panchsteel Park, New Delhi 1998, Curr. Sci. **78** (2000) 102.
2. University of Calcutta, Minutes of the senate and the faculties for the year 1927, Calcutta University Press, Calcutta (1927), p. 84 & p. 801.
3. R. Singh, Bidhu Bhushan Ray - A Pioneer of X-Ray Spectroscopy (Shaker Publisher, Aachen, 2017).
4. Minutes of the syndicate 1923 – Part I & II, Calcutta University Press, Calcutta (1923), p. 320.
5. B.B. Ray to N. Bohr, March 23 (1923).
6. N. Bohr to C.V. Raman, May 18 (1923).
7. Minutes of the senate and the faculties for the year 1940, University of Calcutta, Calcutta (1940), pp. 277-278.
8. R. Tagore to N.K. Sen, September 7 (1935).
9. K.C. Wali (Ed.), Satyendra Nath Bose – His life and times, Selected works with commentary (World Scientific Publishing Co. Ptv. Ltd., New Jersey 2009, p. xxxi).
10. B.B. Ray to Y. Nishina, February 29 (1928).
11. B.B. Ray to N. Bohr, undated (1930).
12. W. Heisenberg to N. Bohr, December 20 (1929).
13. W. Heisenberg to B.B. Ray, January 31 (1938).
14. D. Ray to R. Singh, November 26 (2016).
15. R. Singh, Netaji Subhash Chandra Bose, Bidhu Bhushan Ray and '*Science and Culture*' - History of Science vs. Political history, Sci. Cult. **84** (2018) 103.
16. Y. Nishina and B.B. Ray, Relative intensity of X-ray lines, Nature **117** (1926) 120.
17. B.[B.] Ray, On the effect of chemical constitution on the X-ray spectrum of sulphur, Phil. Mag. (1925) 505.
18. A. Meisel, Der Einfluß der chemischen Bindung auf die Röntgenemissions und absorptionsspektren, Phys. Stat. **10** (1965) 365.

Scientific Voyage
Vol. 1, No. 3,
Page 27-36 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Jul.-Sep.

Pursuit of Inclusive and Sustainable Technology Development for Rural Population: Role of RuTAG at IIT Delhi

Davinder Pal Singh[1], Susha Lekshmi S.U.[2] and Subir Kumar Saha[3]

Department of Mechanical Engineering, Indian Institute of Technology Delhi, New Delhi

Abstract: Countries around the world faces economic, social and environmental challenges in their pursuit towards inclusive and sustainable development. Interestingly, the promotion of sustainable technologies and development remain abstract with vague ethos and understanding. With an aim to strengthen grass root technological innovation and harvest outstanding traditional knowledge for sustainable development, Government of India launched National Innovation Foundation in 2000. In order to integrate higher level of science and technology intervention in the existing technologies at the grassroots, their dissemination, and need based rural development, Principal Scientific Adviser to the Government of India started Rural Technology Action Group (RuTAG) in 2004 at seven Indian Institute of Technologies. The present study gives a philosophical and comprehensive understanding about inclusive sustainable development, United Nation's Sustainable Development Goals (SDGs), Science and Policy Resolution (SPR), and Science and Technology Innovation (STI) in India, various rural programmes, and the significance of Rural Technology Action Group (RuTAG) and its initiatives.

Keywords: sustainable development; demand driven; rural technologies

1. Introduction

Most of the countries around the world face challenges in economic, social and environmental related issues in their pursuit towards inclusive and sustainable development. Requisite ethos and understanding of need, design, development, transfer, and dissemination of sustainable technologies remain vague for sustainable development. As a result, 'sustainability' aspect of the sustainable development always stays at entry level. There is no universal solution to the sustainable development problems considering capabilities, capacities, and policies of each nation. Therefore, transforming the vision of inclusive and sustainable development into reality remains a challenge [1]. Salomyn [2] reported that with rising income inequality especially within and across developing countries, economic progress could not alleviate disparities, rather to have exacerbated it. Gent [3] stated that an increase in Gross Domestic Product (GDP) may not bring equal benefit to all citizens. Though the measure of GDP is useful in measuring the economic growth, it lacks showing how the wealth of a country is distributed. Therefore, the role of inclusiveness is significant in sustainable development as growth and development are not uniformly distributed across all sectors and regions of a country. Officially, sustainable development implies to the development that satisfies the needs of the present generations without compromising the capability of future generations to meet their own needs [4].

---

[1] E-mail: *davinderiitd@gmail.com*
[2] E-mail: *sushalekshmi.su@gmail.com*
[3] E-mail: *saha@mech.iitd.ac.in*

The United Nations' (UN)17 Sustainable Development Goals (SDGs), as shown in Fig.1, adopted by global leaders in 2015 with an agenda to foster the idea of inclusive development is the ultimate pledge to leave no one behind [2].

Fig.1: Sustainable Development Goals (*Source*:[5,6])

The adoption of the SDGs illustrates the paradigm shift in development thinking over the last few decades. Creating the conditions for inclusive and sustainable growth has become the priority of all nations. It has been recognised and established universally that Science, Technology, and Innovation (STI) are the main drivers behind inclusive and sustainable development. UN and other organisations have been pursing governments across the globe to implement sustainable development goals [7]. Apart from strengthening and empowering governments and their governance, the major emphasis of the framework of SDGs, is to mobilize the academic talent by increasing the high-quality institutions and infrastructure which will catalyse and expose its citizens to critical thinking, trouble shooting, innovation, as well as science and technology curriculum. An integrated regional university network is proposed for the implementation of the SDGs, which will amplify the development thinking among millennial [7].

2. India's Vision towards Sustainable Development

India has been progressing gradually in achieving all the SDGs. National Institution for Transforming India (NITI) Aayog have been assigned to direct the implementation of SDGs in the country [8]. The Ministry of Statistics & Programme Implementation (MoSPI) has developed National Indicator Framework (NIF) consisting of 306 statistical indictors to help in statistical monitoring of SDGs and their targets [9]. Also, MoSPI has developed a dashboard on SDGs to monitor the progress of SDGs from national level up to district level as illustrated in Fig. 2. Moreover, India's longstanding tradition and heritage are mirrored in the SDGs, and hence, the SDGs resonate the development agenda of India. India's current Prime Minister himself stated in his speech at the United Nations Sustainable Development Summit in September 2015 that much of India's development agenda is mirrored in the SDGs, and India's national plans are ambitious and purposeful. Sustainable development of one-sixth of humanity would be of great consequence to the world and planet [8].

Scientific Policy Resolution (SPR) which was established in 1958 lays the foundation for drafting all scientific policies in India. Technology Policy Statement (TPS-1983), Science and Technology Policy (STP-2003), and Science, Technology and Innovation Policy (STI-2013) emphasised to proliferate science and technology to improve the weakest section of the population and development of backwards regions [10]. Scientific Policy Resolution anticipated for training science and technical manpower to accomplish the country's needs in science, education, agriculture, industry, and defence. It emphasises to cultivate science, and scientific research in all its pure, applied and educational aspects. The SPR lead to development of many scientific organisations such as Defence Research and Development Organisation (DRDO-1958), the Department of Science & Technology (DST-1971), the Department of Electronics (DOE-1971), the Department of Space (DOS-1972), and the Department of Environment (DOE-1980) [10].

Fig. 2: SDG India Index and Dashboard 2019-2020 (*Source*: [10])

3. Rural India and its Sustainable Development

As per Census 2011, the 15th Census of India since 1872, there are 6, 40, 867 villages in India. Census 2011 projected India's rural and urban population distribution as 68.84% and 31.16% respectively. With 12% increase in the level of urbanization the rural population declined almost 5% with reference to Census 2001. According to Census 2011, the sex ratio of rural and urban are 947 and 926, respectively. Overall sex ratio of India was 900 in 2011. Interestingly, rural-urban literacy rate is 68.8% and 85%, respectively. Literacy rate of male in rural-urban area is 78.6% and 89.7%, respectively, whereas literacy rate of female in rural-urban area is 58.8% and 79.9%, respectively [12]. The data from 1970-71 to 2011-12 shows a continuous decline in the contribution of rural areas to the Indian economy from 62.4% to 46.9%. It is evident from Table 1 that the rural share in the entire national income has been declining sharply since 1970-71 when 84.1% of the total rural workforce produced 62.4% of the total Net Domestic Product (NDP). It can also be substantiated that the major

share of the overall economic growth in the country was contributed by the capital-intensive sectors in urban areas without generating substantial employment from1970-71 to 2011-12. Since 1970 to 2012 India's rural economy has grown from Rs.229 billion to Rs. 34,167 billion with employment expansion from 191 million to 336 million. In spite of seven times increase in output in rural India during the said period, the employment remains stagnant. The growth rates in output and employment for the said period indicate substantial changes across sectors such as agriculture, manufacturing, construction, services, and non-agriculture [13].

Table1: Contribution of Rural areas in Economy and Workforce from 1970-71 to 2011-12 (*Source*: [7])

Year	Economy (%)	Workforce (%)
1970-71	62.4	84.1
1980-81	58.9	80.8
1993-94	54.3	77.8
1999-00	48.1	76.1
2004-05	48.1	74.6
2011-12	46.9	70.9

4. Rural Development Programs

Government of India (GOI) has been fostering and promoting the scientific spirits in the country. Various ministries and departments are promulgating Science and Technology Innovation (STI) through their programmes for poverty eradication and capacity enhancement to masses as depicted in Fig.3.

Also, several other ministries/departments (agriculture; sanitation, drinking water supply, etc.) are transforming lives at the grassroots by implementing schemes and programs at the block/village level, through local bodies and Panchayati Raj Institutions (PRIs) [14]. For the rural development, Government of India have started various schemes and programs such as Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA),Monitoring & Evaluation DIKSHA (Training Portal), Pradhan Mantri Awaas Yojna, National Rurban Mission (NRuM), Pradhan Mantri Gram Sadak Yojana (PMGSY), National Rural Livelihoods Mission, Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY), and National Social Assistance Programme (NSAP) [15].

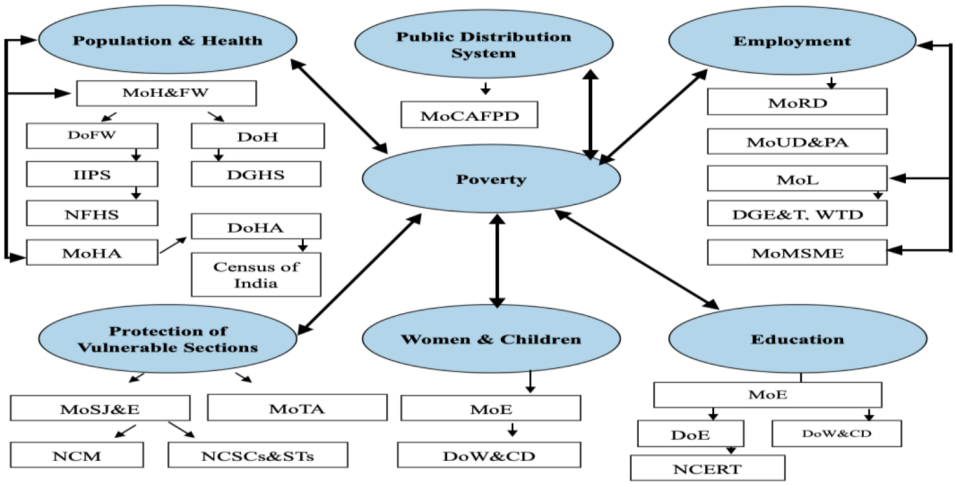


Fig. 3 Government organisations Involved in social sector programs (*Source*: [14])

The symbols used in Fig. 3 are as follows: MoHFW - Ministry of Health & Family Welfare; DoFW - Department of Family Welfare; DoH - Department of Health; MoHA - Ministry of Home Affairs; DoHA - Department of Home Affairs; MoE - Ministry of Education; MoCAFPD - Ministry of Consumer Affairs, Food and Public Distribution; DoW&CD - Department of Women & Child Development; DoE - Department of Education; MoMSME - Ministry of Micro, Small and Medium Enterprises; MoUD&PA - Ministry of Urban Dept. & Poverty Alleviation; MoRD- Ministry of Rural Development; MoSJ&E - Ministry of Social Justice & Empowerment; MoTA- Ministry of Tribal Affairs; DGHS - Directorate General of Health Services; NCM - National Commission for Minorities; NFHS - National Family Health Survey; NCSCs&STs - National Commission for Scheduled Casts & Scheduled Tribes; IIPS - International Institute for Population Sciences; MoL - Ministry of Labour; DoWCD - Department of Women & Child Development; DGE&T - Directorate General of Employment & Training; WTD - Women Training Directorate; NCERT - National Council for Educational Research and Training.

5. Rural Technology Action Group (RuTAG)

Office of the Principal Scientific Adviser (PSA) to the GOI realised the need for Science and Technology (S&T) intervention in the Rural sector (Farm and Non-farm Sectors). Therefore, the Rural Technology Action Groups (RuTAG) has been conceived as a mechanism to provide a higher level of S&T intervention and support through premier institutions to marginalised rural population. These interventions, which are essentially demand-driven, helps in bridging technology gaps, technology up-gradation, technology training and demonstration with the help of S&T NGOs at the grassroot levels. The objective of the RuTAG is to synergize and catalyse the rural development by intervention,design, development and delivery of appropriate technologies. Today, RuTAG is being present in seven IITs situated in Uttarakhand (IIT, Roorkee), Tamil Nadu (IIT, Madras), North East (IIT, Guwahati), West Bengal (IIT, Kharagpur), Uttar Pradesh (IIT Kanpur) Delhi (IIT, Delhi), and Mumbai (IIT, Bombay). Currently 52 different demand driven technologies have been developed by various RuTAG centres at seven IITs which are ready for dissemination. These demands driven technologies caters various sectors like assistive technologies, rural agriculture, draught animal power, rural

energy, rural environment/water, rural handicrafts, and rural textile [16]. With an objective to transfer and disseminate the demand driven technologies, a facility has been created by RuTAG IIT Delhi in collaboration with Foundation for Innovation and Technology Transfer (FITT) at IIT Delhi under the scheme of "Innovative Product Delivery". Field tested technologies are being sold directly to the hands of the users on payment basis through this scheme which are shown in Fig. 4.

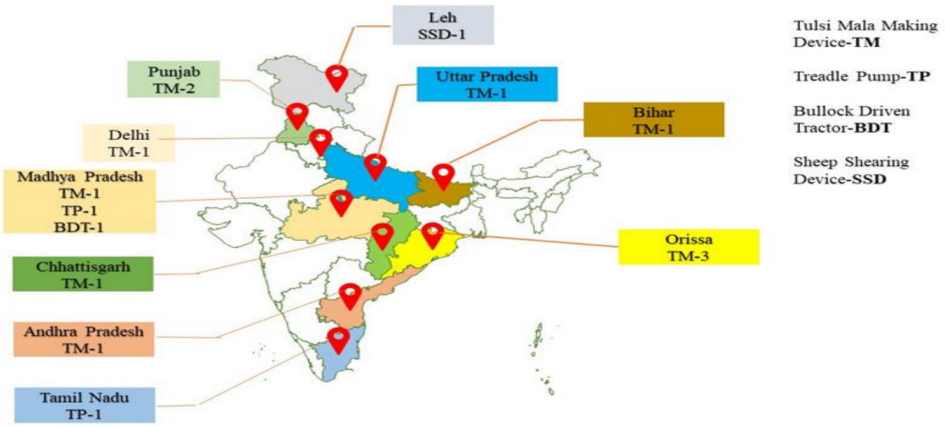


Fig. 4 Various RuTAG IIT Delhi Technologies Sold through FITT IIT Delhi across India

6. RuTAG Technologies at IIT Delhi: Quest for Improvements

Though RuTAG IIT Delhi have done several interventions and developed many field worthy products, its quest for further improvement of the product continues. Feedback from the stakeholders is always incorporated for the product refinement. The journey of the two products, viz. Tulsi mala making device and Treadle pump are mentioned here as examples.

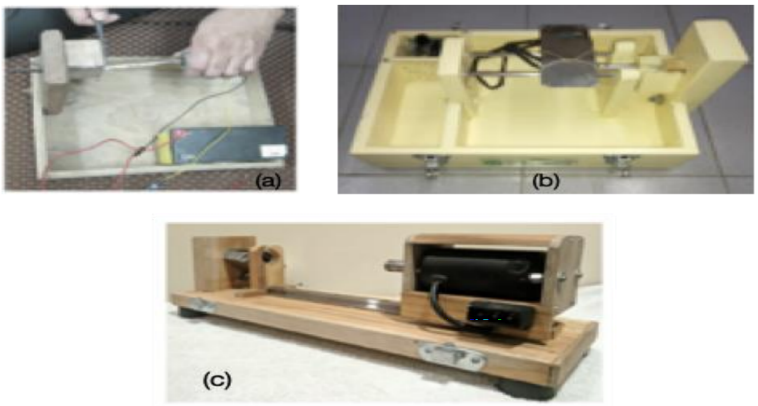


Fig.5: (a) Old version of Tulsi Mala Device; (b)Modified version of Tulsi Mala Device 5mm to 12mm; (c) Latest version of Tulsi Mala Device 5mm to 25mm

Tulsi Mala Device: Various shapes of beads are made from the stems of Holy Basil (Tulsi), Neem, Sandal wood etc. in many villages of India as there is a good demand and consumption of garlands (Malas) throughout the year. Though artisans had devised their own conventional arrangements (refer Fig. 5(a)) for turning, drilling, polishing and cutting of beads from the stem, the process was tiresome which resulted in low productivity and inconsistent quality of beads. As per the need and demand for developing a low-cost device to carry out the effective operations with high productivity and consistent quality of the beads, an ergonomically designed bead making device was developed at RuTAG IIT Delhi [17]. As shown in Fig. 5 (b) and (c), currently two models of the device have been developed according to the need of the artisans. Figure 5(b) shows the model which has the capacity of producing beads of 5mm to 12mm beads and runs on DC as well as on AC supply, Fig 5(c) shows the model which has the capacity of producing 5mm to 25mm and runs on AC supply [17]. Both the models have been evolved through continuous feedback and engagement with the artisans of different clusters.

Treadle Pump: Though treadle pumps have been used extensively, farmers expressed the need for improving their ergonomic design to make its operation less cumbersome. Further, the problem of rapid wearing out of the piston washers was also reported [16]. As per the demand and requirements, more efficient and user-friendly models of treadle pumps were developed by RuTAG IIT Delhi. Figure 6 (a) shows the model which was developed as per the skills of the existing fabricator at the village and Fig. 6 (b) shows the model which was made using standard plumbing and handpump spare parts. Both were improvised from the feedback of the stakeholders. A complete ergonomic study on the improvised version of treadle pump is under investigation by a Ph.D. research scholar.

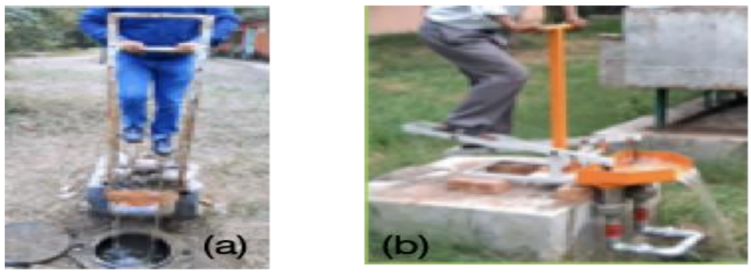


Fig. 6: (a) Treadle pump as per the skills of the fabricator and (b) Treadle pump using standard plumbing and handpump spare parts

7. RuTAG: Research Connect and Internationalization

In order to emphasise the strong need of basic research and disseminate the research results, Rural Technology Development and Delivery (RTDD), an International Conference added a new dimension in 2018 to the RuTAG by providing an international platform to integrate the RuTAG activities with rest of the world. It has motivated researchers, students, and academic/Research and Development (R&D) institutions, and rural entrepreneurs for getting them involved as well as acquainted with the challenges associated with developing

appropriate technology development for rural areas in India as well as across the world. Already, two international conferences were held at IIT Delhi (2018) and IIT Madras (2020). This effort has strengthened the academic integration of the RuTAG activities which should continue synergizing with other similar initiatives of collaborating with national and international academic institutions. RuTAG Club is an initiative by RuTAG IIT Delhi to create awareness about rural problems and develop interests for rural technical interventions among IIT Delhi students. Moreover, IIT Delhi students and faculty members from various disciplines have taken up various RuTAG problems for their mini projects as well as Summer Undergraduate Research Award (SURA) projects to fulfil their academic requirements. Further, RuTAG IIT Delhi promotes multi-institutional collaboration through which students from various institutes can take up RuTAG project as their internship projects. So far, RuTAG IIT Delhi has collaborated with NIT Durgapur, College of Engineering and Mangement, Kolaghat, and S.R. Engineering College Warangal. RuTAG IIT Delhi publishes half-yearly newsletters which showcase valuable source of information on the rural research going on at different parts of the countryby various RuTAG centres, and various activities of RuTAG IIT Delhi. In order to reach out RuTAG technologies in regional areas, recently, RuTAG newsletters are also being translated to some regional languages viz. Bengali and Odia.

The integration of RuTAG with an international institution with similar mandate for helping the rural communities, RuTAG IIT Delhi started collaborating with EPICS (Engineering Projects in Community Service) at Purdue University in Indianapolis, USA. The basic objectiveof this collaboration is to promote sharing of technical knowledge among countries by jointly solving rural/community problems. EPICS has been acquainted students to RuTAG program since September 2017 and ever since students have taken up various problems from rural India and tried to provide solutions with different perspectives. Currently students at EPICS are working two RuTAG problems Bullock Driven Tractor (BDT) (refer to Fig. 7) and Prevention of Stone Dust Inhalation. Also, Shah Global Innovation Labs at Purdue university have expressed their willingness to jointly solve the community problems along with RuTAG IIT Delhi.

Fig. 7 EPICS students working on BDT

8. Conclusions

A great thrust has been generated towards the development and widespread applications of Science and Technology for sustainable development at the grassroot levels. A tangible and real thrust towards sustainability can only occur through a change in the worldview identifying the purpose, needs and relationship with other human being and rest of nature correctly. It is crucial to acquire right understanding about sustainable "happiness" and "prosperity". Then, it is also essential to recognize the co-existential and highly interconnected characteristics of existence and accordingly identify our own role. This realization will lead to mutually fulfilling human relationships and mutually enriching interaction with rest of nature which is so vital for promoting sustainability. Endowed with such a worldview, we shall be able to chalk out effective strategies to move towards inclusive sustainable development. Rural Technology Action Group (RuTAG) is one of such strategies aiming development and dissemination of demand driven technologies for inclusive sustainable development. The present study also gives a brief review on the need for inclusive sustainable development, SDGs, and science and technology interventions at the grass root level technologies.

Acknowledgements: We sincerely thank the Office of the Principal Scientific Advisor to the Govt. of India for their financial support to RuTAG IIT Delhi. Dr. Susha Lekshmi S.U. would like to acknowledge the Science and Engineering Research Board (SERB), Department of Science and Technology (DST) for providing financial support under the NPDF scheme. The encouragement of Dr Ketaki Bhapat (Scientist 'F'), Prof. R.R. Gaur (Chairman, RuTAG IIT Delhi), Prof. Sangeeta Kohli (Co-Coordinator RuTAG IIT Delhi) and Prof. M.R Ravi (Co-Coordinator RuTAG IIT Delhi) is highly appreciated. Authors are thankful to RuTAG IIT Delhi Team member Mr. Yashwant Prasad (Project Associate RuTAG IIT Delhi), Mr. Suraj Bhat (Research Scholar RuTAG IIT Delhi), Mr. Raj Kumar Gupta (Sr. Project Assistant), Mr. Ashish Dahiya (Jr. Project Assistant (Tech.)) and Mr. Mangal Sharma (Project Attendant).

References:

1. R.R Gaur, *Chairman's Column RuTAG Newsletter* 7(2) (2019).
2. C.J. Salomyn, *UNDP's strategy for inclusive and sustainable growth* (UNDP, Art Direction & Design, New York, USA, 2017).
3. S. Van Gent, *Beyond buzzwords: What is «inclusive development»* (Synthesis report INCLUDE Secretariat, Hague, Netherlands, 2017).
4. *Report of the World Commission on Environment and Development: Our common future* (1987).
5. *United Nations Millennium Development Goals Report 2012* (New York, NY: United Nations, 2012).
6. Sustainable Development Goals 2020 (United Nations Development Programme; https://sdgindiaindex.niti.gov.in/#).
7. ESCAP-2016: *Harnessing Science, Technology and Innovation for Inclusive and Sustainable Development in Asia and the Pacific* (ONU, New York; https://doi.org/10.18356/47177795-en).
8. Aayog, N.I.T.I.-2017: Voluntary National Review Report on Implementation of Sustainable Development Goals. In *United Nations High Level Political Forum; http://niti. gov. in/writereaddata/files/Final_ VNR_report. Pdf* (2020).

9. India SDG Dashboard-2020: *Ministry of Statistics and Programme Implementation, Government of India*; http://www.sdgindia2030.mospi.gov.in.
10. B.P. Singh, Science Communication in India: Policy Framework, *J. Sci. Temper* **2**(1 & 2) 2014.
11. SDG India Index and Dashboard 2019-2020: NITI Aayog, United Nations; https://sdgindiaindex.niti.gov.in.
12. C. Chandramouli and R. General, Census of India 2011, Provisional Population Totals, New Delhi: Government of India, pp. 409-413 (2011).
13. Aayog, N.I.T.I.-2017: *Changing structure of rural economy of India implications for employment and growth*, National Institution for Transforming India, Government of India.
14. I.J. Khalkho, Poverty Eradication and Human Resource Development, *Anusandhanika* **4** (2012) 76.
15. Annual Report 2019-20, Ministry of Rural Development, Government of India; https://rural.nic.in/sites/default/files/AnnualReport2019_20_English.pdft.
16. S.K. Saha and Susha Lekshmi S.U., *A Compendium on Rural Technology Action Group (RuTAG)-Demand Driven Technologies for Rural Entrepreneurship*, RuTAG IIT Delhi; https://drive.google.com/file/d/1jMOYmJoKJrHYW6_irDjanlicC71D0WNF/view (2019).
17. Y. Prasad and S.K. Saha, *Development of an AC Motor Powered Device for Making Tulsi Mala Beads*, Conference presentation, 2nd International Conference on Rural Technology Development and Delivery, IIT Madras (2019).

Scientific Voyage
Vol. 1, No. 3,
Page 37-46 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Jul.-Sep.

Cloud-based automated blood management system

Sougata Sil[1] and Somaditya Roy[2]

[1] *Department of Computer Science & Engineering, Techno Engineering College Banipur, Banipur College Road, Habra 743233, West Bengal;* E-mail: *sougatasil2001@gmail.com*

[2] *Department of Information Technology, Techno Engineering College Banipur, Banipur College Road, Habra 743233, West Bengal;* E-mail: *rsomaditya@gmail.com*

Abstract: From decades, donating, managing, and receiving blood throws a great challenge for the whole human civilization. If there is an excellent blood management system, death due to unavailability of blood along with blood wastage could be reduced. This paper presents a website for online blood management facility. The proposed system consists of three subsystems for real-time blood request response using JavaScript data shuffling and an optimized search for the same; blood bank stock balancing and scientific management and scheduling of blood donation camps by clustering data and performing nested SQL queries for data analysis. This would be an advancement of the classical blood management model to an automated system using web technologies (HTML,CSS, SQL, JavaScript, php). The prototype is carried out using sample data. The system evaluation and analysis are provided .

Keyword: Blood management system; interactive website; real-time communication; stock-balancing; search optimization; clustering; notifying; suggesting; prevention of blood wastage; data analysis

1. Introduction

In recent years, with the rapid development of medicine, health improved a lot. At the same time, health professionals failed to solve many problems [1], that pose a serious threat to the human civilization, therefore the field of health and technology is now a popular research topic, to deal with such problems technically in an automated way of blood management with user convenience in mind compared with the manually operated existing system [2].

In this website, users can be of four types – Donors, Blood Banks, Blood donation camp organizers and recipients. Users can register or login as a guest to avail our services.

Our services to:

Recipients: Searching for blood, Searching and requesting blood as registered users or unregistered guest users.

Donors: Notifying for blood need requests according to location analysis and making specified blood group holding donors aware of blood donation camps.

Blood Banks: Notifying for blood need requests according location analysis and suggesting for balancing stocks according to location cluster need.

Blood donation camp organizers: Notifying for organizing blood donation camps when at certain location cluster there exists a huge range of difference between stock and requirement and informing specified donors about specified blood group blood donation camps.

This paper focuses on implementing these solutions technically to solve the mentioned problems integrating in a website [3]. In addition to all the steps, we have followed a design thinking approach to enhance the proposed solution [4]. We expect to achieve good results in the worse environments, to provide the recipient with blood with ~100% positive results and as fast as it could be.

To conduct the experiment with the prototype of the website, we are using manually made sample user database [4].

The sample database consists of tables for Individual donors(t2) , Blood banks(t1), blood search query log(ureq), user location reference (location_grid), location clusters (l1, l2, l3, l4…). (t1) & (t2) consists of unique user id, name, blood group and available blood groups respectively. (ureq) consists of user input data during generating a search query for required blood.(location_grid) consists of location clusters with each assigned a set of latitudes and longitudes so as to group users according to their location and include them in a specific location cluster. (l1, l2, l3, l4…), are the location clusters, each with the fields of need and requirement for every blood group.

2. Proposed System

2.1 Use Case Diagram

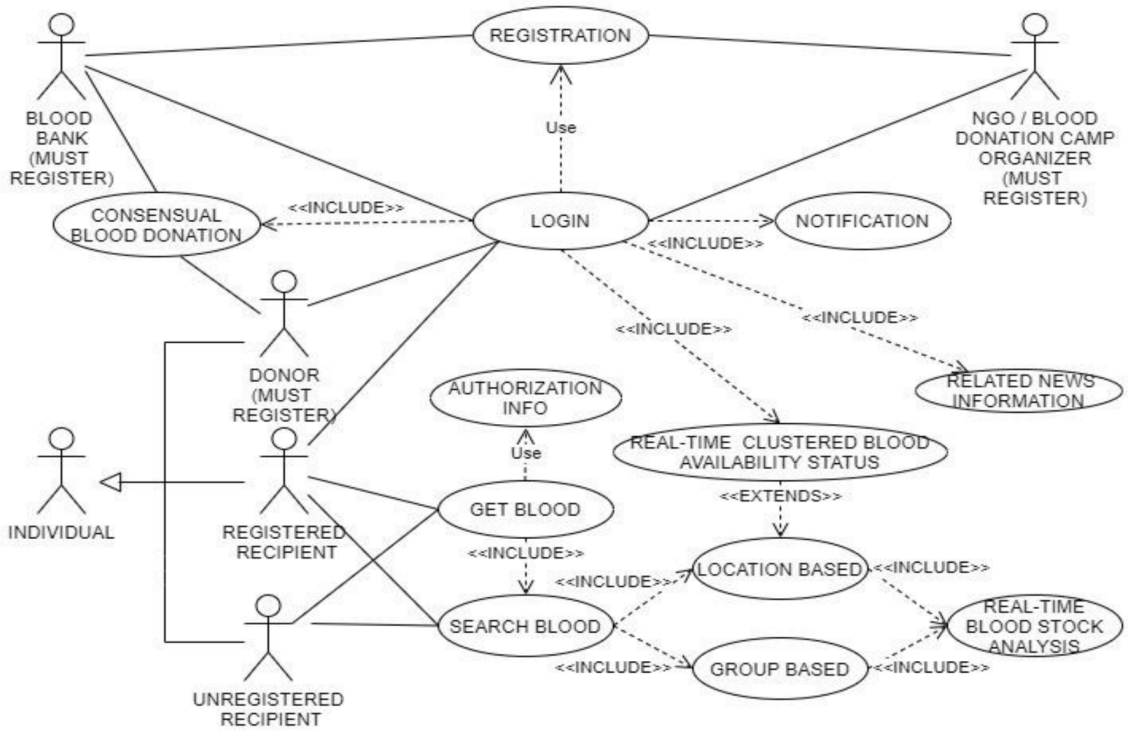


Fig.2.1: System Use Case Diagram

2.2 System Structure I

System structure I describes the user registration/login system according to the type of user. On visiting the home page of the website, the user will be offered with an option of (registration or login) 1. He/she may register into the system or can avail the services as guest [5,6]. To be a donor the user (individual/blood bank) must register into the system, to access their data during a search request.

The user will be redirected to a page consisting of the three types of users on clicking (1), from which the user can register or login to his/her profile [7].

Fig.2.2: Registration/Login

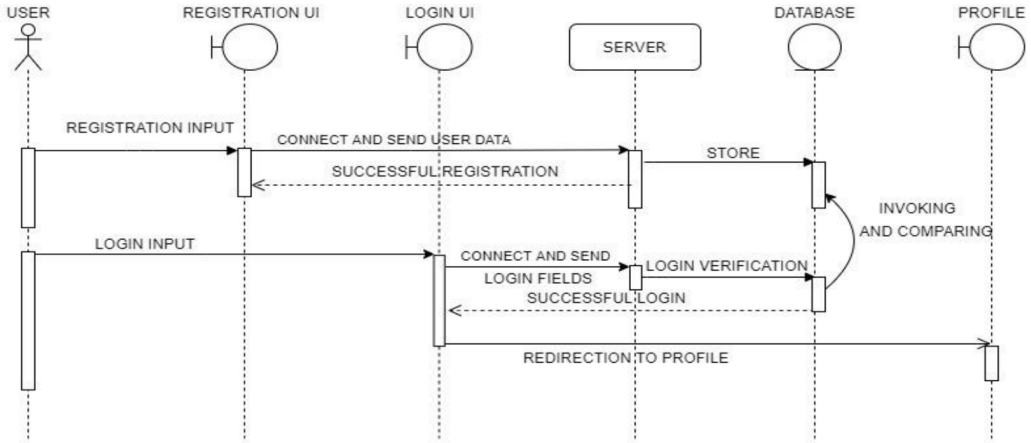


Fig.2.3: Registration/Login Sequence Diagram

This figure illustrates the part of the prototype dealing with the registration and login. The structure of the illustration is made & connected using HTML and the form is validated using JavaScript. The submit button sends the data from the form to the respective tables in the database according to the type of user; using the 'POST' method, ensuring security of the personal data. Login button redirects an existing user to a login page so as to give the user access to his profile after verifying the user name and password from the user entered data during the registration, this is also done using the 'POST' method.

After the login, user is redirected to their own profiles where they can access various activity tabs according to their need. The activities include going to the home page for accessing the blood searching and blood request services through the GO TO HOME tab; NOTIFICATION tab for accessing notifications; STATISTICS tab for viewing the stock vs need statistics for each blood group of each location cluster according to the user searched location cluster. This STATISTICS tab is same for all user profiles [5-7].

In this experiment, the registration system will not be focused, as we will be using sample data as described earlier, instead we will login with the username and password to enter into our profiles as individuals, blood banks and blood donation camp organizers. We will also avail the services being a guest user to the website prototype [4].

2.3 System Structure II

System structure II describes the control flow and algorithms involved in the process of Blood searching and Blood request.

2.31 Searching Blood

The blood searching unit is the section of the homepage, where the user can login as guest or as registered user and can avail the specified service, the service can be defined as searching for blood with required parameters among various blood banks and individual donors connected with our system. Through this blood searching unit, the user can only search for blood without disclosing his/her identity that is being anonymous. The search unit deals with both registered and unregistered users therefore there need some privacy protocols to be maintained, so as no donor information is disclosed. Keeping these factors (2) in mind, this search unit only displays the number of matched donor individuals according to the input parameters entered by the user.

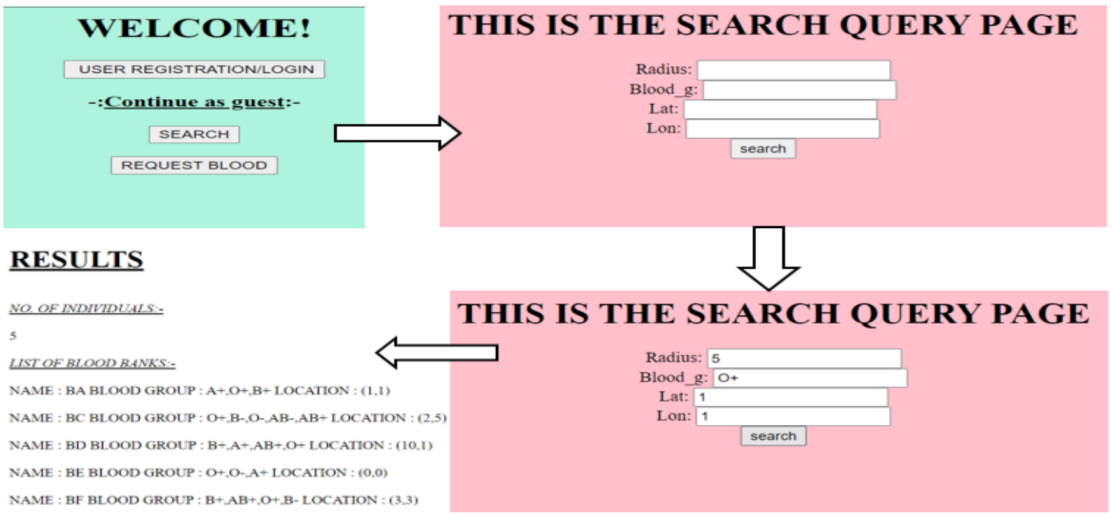


Fig.2.31(A): Search query flow

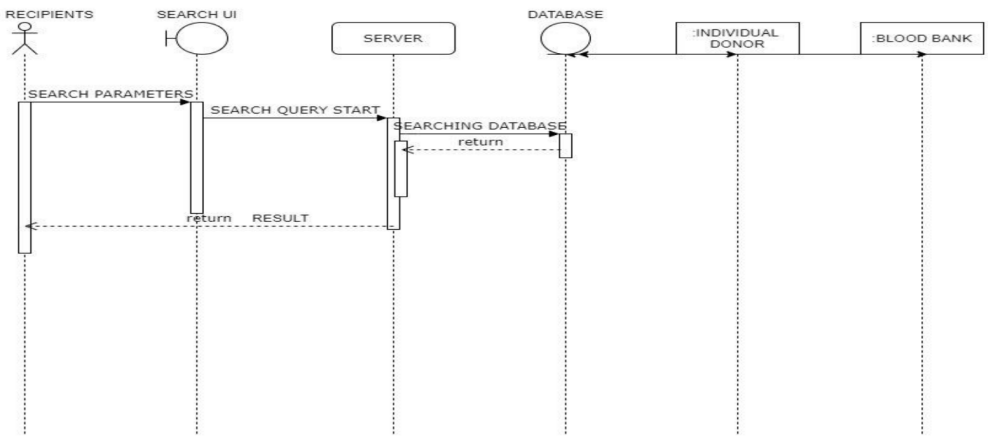


Fig.2.31(B): Blood Search Sequence Diagram

The mentioned figure illustrates the process of Blood Search from the home page to the results of the search query generated by the user with the mentioned parameters.

This process includes three steps of redirection with the 'POST' method, firstly on clicking the *Search* button in the HTML structured home page, it redirects user to a search query page. This page allows the user to search blood (individual donors & blood banks) keeping three parameters as the filter of the result. The parameters include radius in which the search should be applied as *radius,* the required blood group for which the user wants to search for as *Blood_g* and the current location of the user. In this experiment with the prototype, the location is manually taken from the user in the form of latitude and longitude; in the real scenario, the website will be accessing the current GPS location of the system used by the user. In this way the parameters will be addressed. On clicking the search button, the backend search query that is the SQL embedded php code filters and fetches the table data from the tables of the database inside the phpmyadmin panel to the display

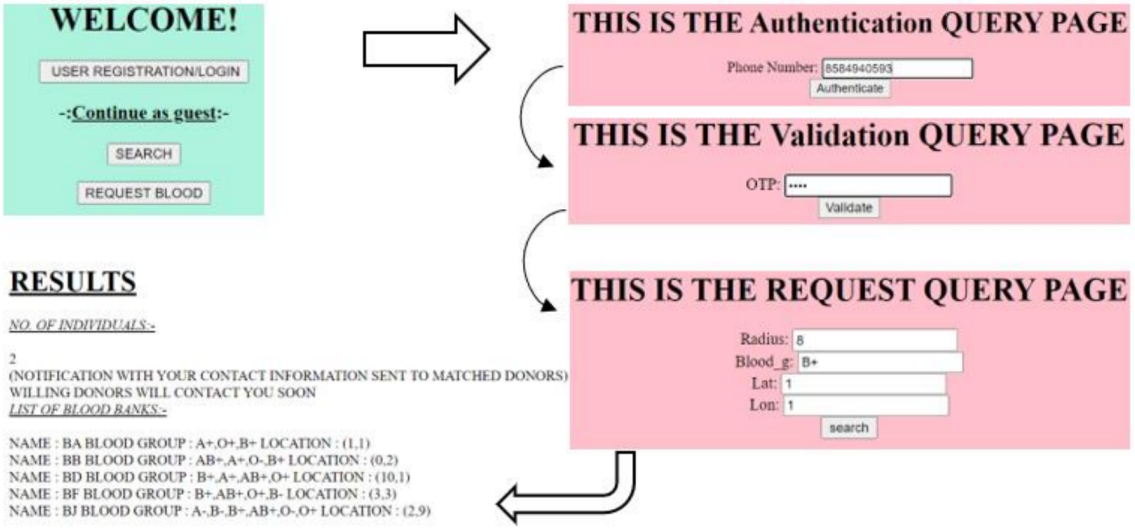


Fig.2.32(A): Request query flow

section. After clicking on this search button, the user is redirected to search results page, where the fetched-out information is displayed in an user readable format [5,8]. From the previous discussion (2), due to these security issues, in the result section, only the blood bank information and the number of matched individual donors is being displayed hiding the information about these individual donors.

2.32 Requesting blood

The blood requesting unit is the section of the homepage, where the user can login as guest or as registered user and can avail the specified service, the service can be defined as requesting (that is searching for matched individual donors and blood banks and then sending a notification request to the matched individual donors for contacting the user generating the request) for blood with required parameters among various blood banks and individual donors connected with our system. Through this blood requesting unit, the user can both search and request for blood keeping his/her personal information into our database as an entry log data. The request unit deals with both registered and unregistered users therefore there need some security measures to be maintained, so as no donor information is disclosed unauthentically to any user. Keeping this factor in mind, the request unit is optimized to authenticate and validate the user using an OTP service [9] as soon as the user enters the Request Blood section, before giving him access to the request query page.

The mentioned figure illustrates the process of Requesting Blood from the home page to the results of the search and request query generated by the user with the mentioned parameters.

This process includes four steps of redirection with the 'POST' method, firstly on clicking the Request blood button in the HTML structured home page, it redirects user to a user authentication page using phone number as the authentication source to start an OTP (One Time Password) service. After submitting the phone number, the system keeps record of it as log data and then an OTP is sent using php code to the entered phone number and the user is then redirected to the phone number validation page. This page allows the user to enter the sent OTP and validate the user so as give access to the next page that is the request query page (if the OTP matches with the sent OTP of that specific php session; access is given, otherwise denied). This page allows the user to search & request blood (individual donors & blood banks) keeping three parameters as the filter of the result. The parameters include radius in which the search should be applied as radius, the required blood group for which the user wants to search for as Blood_g and the current location of the user. In this experiment with the prototype, the location is manually taken from the user in the form of latitude and longitude; in the real scenario, the website will be accessing the current GPS location of the system used by the user. In this way the parameters will be addressed. On clicking the search button, the backend search query that is the SQL embedded php code filters and fetches the table data from the tables of the database inside the phpmyadmin panel to the display section. Besides that, a notification is sent to the matched individual donors. The notification consists of two options to AGREE and DISMISS. If the notification is agreed, the contact information of the recipient will

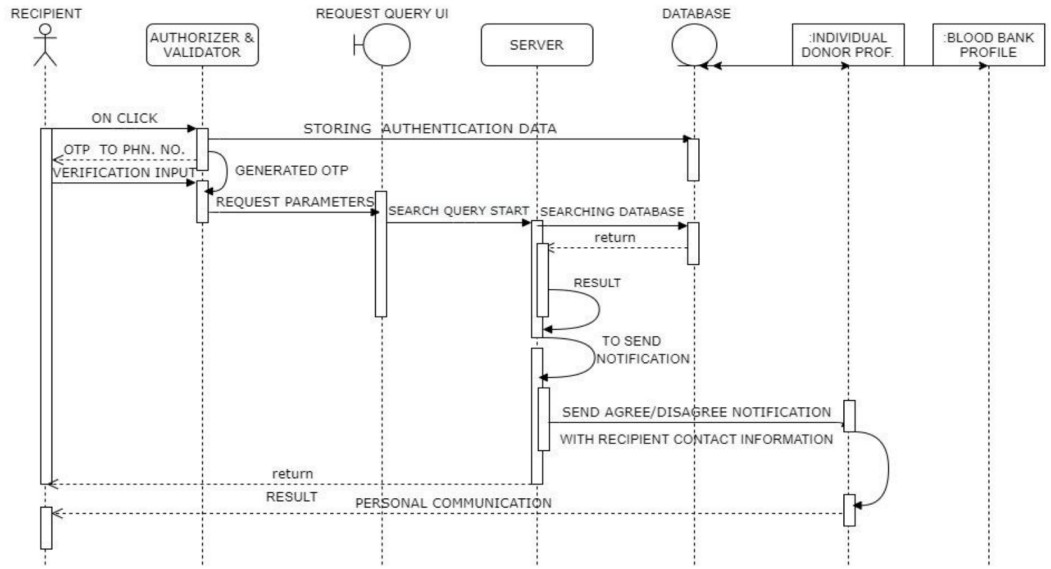


Fig.2.32(B); Blood Request Sequence

be made transparent to that donor then he/she can contact the recipient and move for further steps for successful donation. If the notification is disagreed, the request ends up for that user and continues for the rest. Besides, the user is redirected to search results page, where the fetched-out information (matched blood bank information, number of matched individual donors, notification sent status and number of agreed and disagreed) is displayed in an user readable format. From the previous discussion (2), due to these security issues, in the result section, only the blood bank information and the number of matched individual donors is being displayed hiding the information about these individual donors [8-11].

2.4 System Structure III

System structure III deals with the process of generating notification for balancing blood bank stocks and scientific organization of blood donation camps by the blood donation camp organizers to reduce blood wastage.

(Whole blood lasts for only 42 days, after that the expired blood is thrown away . According to a study annually 6.67% of donated blood is discarded due to its unutilization in proper time. This leads to a loss of (1.3-1.4) million rupees for the blood banks annually.)[12]

This system structure will be further divided into two segments as mentioned previously Blood Bank Profile and Organization profile. The two entities could access their respective profiles by logging in to their profiles through the login/registration button at the home page as described in the *SYSTEM STRUCTURE-I*. Both the entities will be redirected to a similar structured profile pages with three tabs: *GO TO HOME, STATISTICS, NOTIFICATION*; but with different contents of the notification tab. The *GO TO HOME, STATISTICS, NOTIFICATION* tab will redirect the user to the home page, location-based (stock vs requirement) statistics and the specific notification page respectively. The same *GO TO HOME&STATISTICS* tab will be available in the profile of every user category [13].

2.41 Blood Bank Profile

After the successful Blood Bank login, the user will be redirected to the Blood Bank profile page with the mentioned tabs.

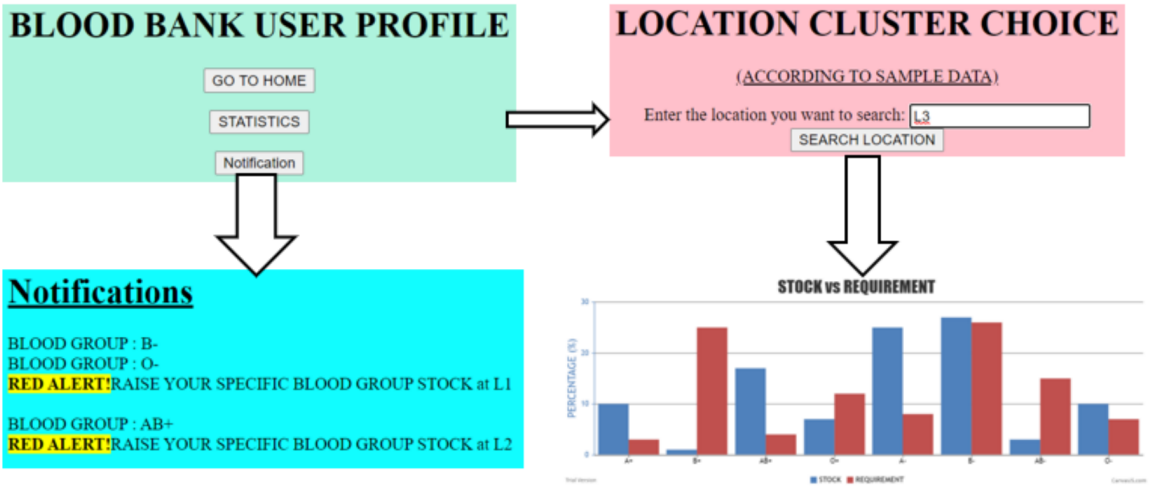


Fig.2.41; Blood Bank profile flow

In the illustrated figure, after clicking on the *STATISTICS* button, the user is redirected to the location cluster page so that the user can view the stock vs requirement statistics of any location the user wants to by simply searching the location cluster in the search location field. The *NOTIFICATION* button redirects the user to the blood bank notification page, where he/she can view the blood bank stock suggestions given by our system according to the location cluster requirement.

A. THE STOCK VS. REQUIREMENT STATISTICS

(In this experiment we are using sample location cluster data as L1, L2, L3…; without entering the real-world location values.)

After clicking on search location button, the JavaScript code embedded with php and SQL, searches for the location table entered in the location field from the database. Then the php code fetches the rows of the tables that is the stock and requirement data for each blood group and initializes it to the JavaScript variables that are used to create and display those data as a visual representation in the form of bar graph.

In the given bar graph, the y-axis denotes the percentage of units of blood and the *x*-axis denotes the eight blood groups (A+, B+, AB+, O+, A, B-, B-, O-).The blue bar denotes blood stock present in that specific location cluster and the red bar denotes the amount of blood needed in that location cluster. The value of the stock column is calculated by accessing the stock databases of the blood banks present in that location cluster. The requirement data is generated by calculating a population-based blood group ratio of that location cluster.

For this process, firstly the registered users are clustered according to their respective location using SQL query, then on every such clustered data, a nested clustering is done based on each of their blood groups. Thus, the ratio is generated which can be assumed as the actual requirement ratio when we have a huge database. Now, in the statistical representation, the bar graph we are using these two data sets to understand the comparison between the Blood Stock and Requirement for a specific location cluster.

B. BLOOD BANK NOTIFICATION

(In this experiment we are using sample location cluster data as L1, L2, L3…; without entering the real-world location values.)

After clicking on the NOTIFICATION button, the html code redirects the user to the blood bank notification page. The notification page backend SQL embedded php algorithm takes the access of the blood bank stock data of the user and the neighbouring blood banks of that location and checks weather the blood stock and requirement difference(from the previous section of statistical calculations) is less than 5%, then NO WARNING; if greater than 5% & less than 20%, then alert message for upraising the blood stock of that specific blood group. Thus blood is balanced at every location cluster to provide the fastest service and positive availability at the nearest blood bank.

2.42 Organization Profile

After the successful Blood Bank login, the user will be redirected to the Blood Bank profile page with the mentioned tabs.

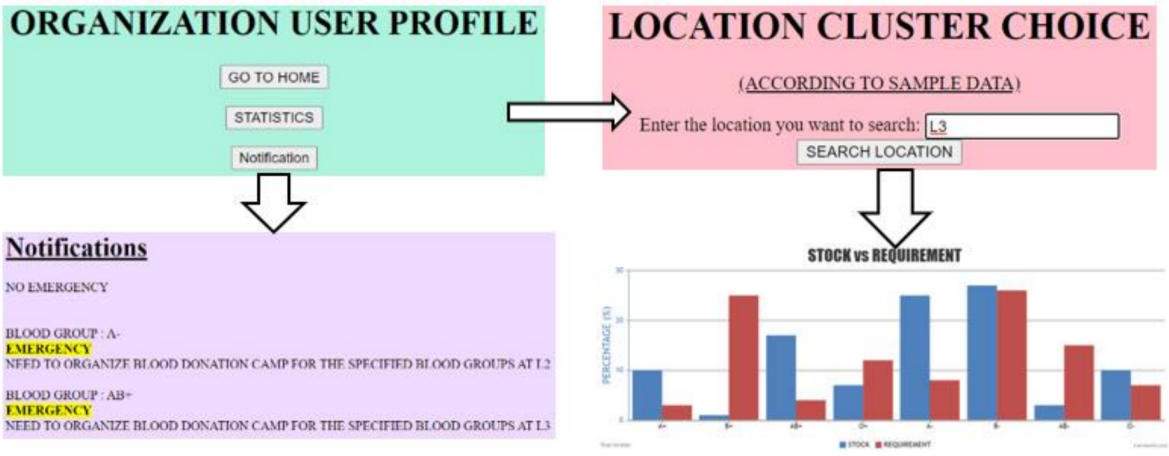


Fig.2.42; Organization profile flow

In the illustrated figure, after clicking on the *STATISTICS* button;*[same as blood bank profile statisticssection, statistics tab is same for every user]*. The *NOTIFICATION* button redirects the user to the Organization notification page, where he/she can view the notification for organizing blood donation camps at specific locations according to the suggestions given by the system.

Organizing blood banks is the final option to balance blood stocks at blood banks according to the location requirement when the blood bank stock management suggestion fails to balance the blood stock.

In this process, as soon as the organization user is redirected to the notification page, the backend SQL embedded php algorithm checks for the difference between Stock and Requirement data sets from the statistical calculations as described earlier. If the difference for one or more blood group is greater than 20%, then an emergency notification is sent to the blood donation camp organization with the location and those specific blood groups which are deficient so as to organize an blood donation camp only for those specific deficit blood groups. At the same all the individual donors within that location cluster, with those specific blood group holdings will be sent an notification regarding the blood donation camp with the location of the event, thus only collecting that deficient blood group to fulfil the need and not to store excess blood, leading to blood wastage.

3. Results and Discussions

After the successful testing of the system for accuracy, using a small set of sample database, now the system will be tested for its capability to work with large databases and the execution of the queries with time complexity approach.

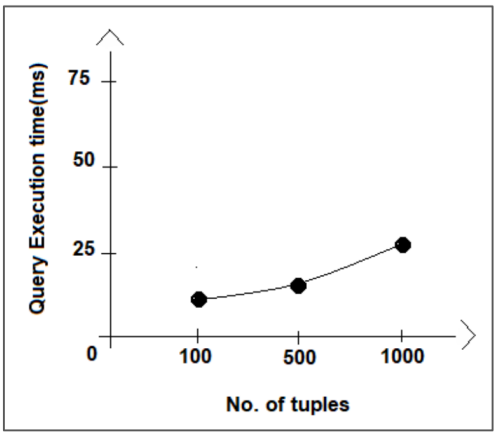


Fig.3.1: PROPOSED SYSTEM

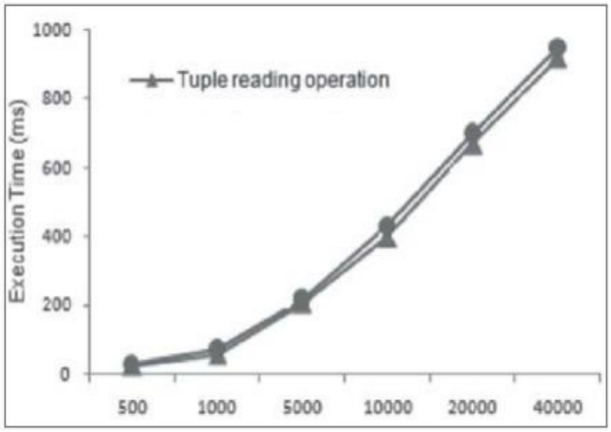


Fig.3.2: EXISTING SYSTEMS

The Figs. 3.1 and 3.2 illustrates a graphical representation of the query execution speed (in milliseconds) to the number of tuples in the database from which it fetches & filters the data and displays it to the user.

The comparison the two figures proves that the proposed has attained the execution speed required to handle huge data traffic. On detailed analysis, it can be observed that the slope of Fig. 3.1, is much efficient than the existing systems [14] when the experiment is done by generating a huge user database by looping randomize function and returning the value into the tuples of the tables in our database. These experiments provide us with a descent feedback and expected results.

4. Conclusion

This paper presents a scientific Blood Management System designed to help people in need of blood and blood banks to search and request and avail blood faster with a positive impact and to prevent wastage of blood and money and time. The system (website) is divided and maintained with many subsystems. All these

subsystems integrate to make a positive change to the current health care system that is the blood management system.

- Automated system of blood management (A website)
- Easy and positive search result for the required blood
- Predicting zonal blood stocks, to make it available before vacancy
- Time to time management of blood donation camps to overcome blood wastage
- Faster, accurate and secured real-time responses

The future aspects of this project are enormous. This will include statistical analysis on health factors, trend of diseases on a blood group, after a huge user base; data marketing for health research and lot more using Machine Learning algorithms. Our future works will also include updating our system from a website to an app to make it more user friendly and attractive and popular for the use of common people [15].

Acknowledgment: SS expresses his sincere gratitude to the rest of the team members for their insightful comments and encouragement, and for the hard questions which inspired me to widen up my thoughts from various perspectives.

References:

1. K. Ghosh, *Ind. J. Hematol. Blood Transfus*., **34** (2018) 501.
2. K. Vikas, M. Sharad, *IJE* **1** (2011) 260.
3. S. Shrinivas, V. Vijay and S. Yennam, *IJARIIT* **3** (2017) 218.
4. R. Garett et al., *J. Commun. Media Technol.* **6** (2016) 1.
5. P. Kumari and R. Nandal, *IJARCS* **8** (2017) 1231.
6. M. Fotachea and C. Strimbei, *Proc. Econ. Finan.* **20** (2015) 243.
7. L. Lemay, R. Colburn and J. Kyrnin, Mastering HTML, CSS & Javascript (Web Publishing, 7th Edition, BPB publications, 2016).
8. A. Sumita, Computer Science with C++, Database, SQL, Boolean Algebra, Networking Basics (11 Edition, Vol. 2, Reprint 2017, Dhanpat Rai & Co.(P) Ltd. Publication).
9. M.H. Eldefrawy, K. Alghathbar and M.K. Khan, 8th International Conference on Information Technology: New Generations, pp. 327-331, July 2011.
10. M. Joel and H. Ray, Murach's PHP and MySQL (3 Edition, Reprint 2017, MMA publication).
11. M.S. Rahman, K.A. Akter, S. Hossain, A. Basak and S.I. Ahmed, IEEE Workshops of International Conference on Advanced Information Networking and Applications, pp. 544–548 (2011).
12. S. Hisham, A. Al-Madani, A. Al-Amri, A. Al-Ghamdi, B. Bashamakh and N. Aljojo, *Life Sci. J.* **11** (2014) 60.
13. D. Pandey, A. Umare and R.S. Mangrulkar, IJRSE **3** (2017).
14. A. Gaikwad et al., *IJTSRD* **2** (2017)1027.
15. S. Roy and S.K. Bandyopadhyay, *Int. J. Res. Info. Tech.* **1** (2013) 248.

Scientific Voyage
Vol. 1, No. 3,
Page 47-54 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Jul.-Sep.

An overview of cybersecurity risks during the COVID-19 pandemic period

Soumit Chowdhury [1], Soumya Mukherjee [2], Saranya Naha Roy [3], Rashed Mehdi [4]

and Rishav Banerjee [5]

Department of Computer Science and Engineering, Government College of Engineering and Ceramic Technology, Kolkata 700010, West Bengal, India

Abstract. The COVID-19 pandemic has affected lives of billions of people around the world. The pandemic has and will continue to transform and shape the digital world. New measures are being taken to cope with social distancing norms prevalent around the world. Booming telecommuting, dependence on e-services, virtual events, movement of infrastructure to clouds have become common. All these changes have severe security implications. This paper analyses how people can be affected from the cybersecurity aspect. It highlights some of the most common methods by which people can be manipulated into revealing information resulting in loss/theft of money and/or intellectual properties. It also spells out some common measures that can be taken to dispel much of the risks. Overall, this presented study has tried to highlight most of the potential threats in the digital platform with specific supporting data. Additionally, the paper also focuses on some effective mechanisms to handle these critical issues especially in this pandemic situation of COVID-19.

***Keywords*:** Cybersecurity; COVID-19 pandemic; phishing; cybercrime

1. Introduction

The COVID-19 pandemic has affected life in an unprecedented way. Throughout the world, governments have issued directives for hospitals and other health care facilities to take more precautions and ramp up their resources, for businesses and schools to close, and for individuals to maintain safe social distancing or quarantining if necessary. Digital trade is slowly picking up pace to fill up the void left due to the absence of marketplace trade. After a brief government-imposed hiatus, e-commerce is slowly making its way and is expected to grow much more over the upcoming few months. E-wallets and electronic transactions are gaining traction much more than ever. Medical practitioners are using tele-health services to treat non-critical patients. These have contributed to the need for a digitally connected world that requires transfer of sensitive information. Unfortunately, unscrupulous persons have jumped to the occasion and are using this opportunity to the fullest extent for their benefit. While no one can predict how long the corona virus effects will last, all of us can educate ourselves and take action to protect our identities and wallets.

Main objectives which this report focuses on are as follows:

- 1. Cybercrimes have become a serious threat during this situation as the majority of communications are being done online. Thus, the report aims to discuss the different types of cyber threats in order to spread awareness among the masses.
- 2. The report also focuses on different effects and consequences of the cyber attacks based on previous records, reports and surveys in order to make a concrete understanding of the present situation of the risks associated with cyberspace.

---

[1] E-mail: *joy_pinu@yahoo.co.in*
[2] E-mail: *soumyamukherjee@mail.com*
[3] E-mail: *saranyanaharoy@gmail.com*
[4] E-mail: *rashedmehdi42@gmail.com*
[5] E-mail: *rishav16ban98@gmail.com*

- 3. The report also discusses different methodologies that can be employed to prevent and protect the digital infrastructure of the country and the masses against these cyber attacks.

2. Cybercrime

Cybercrimes are criminal activities carried out by hackers, a group of hackers, organizations, or are often covertly state-sponsored that target computers or a group of computers connected to a network. Cybercriminals are often extremely skilled. They know ins and outs of the systems they are hacking and use advanced techniques that are used to evade security mechanisms in place. Some studies show that due to the government-imposed lockdown and social distancing rules, many criminals have gravitated towards organized cybercrimes [1]. Most commonly cybercrimes are organized for monetary benefits, while others have political or personal motives [2]. Cybercrimes are broadly divided into a couple of categories:

(i) *Crimes that target networks or devices:* Malwares like virus, rootkits and DOS attacks,

(ii) *Cybercrimes that use devices to participate in criminal activities:* Phishing emails, cyberstalking and Identity Theft.

2.1 Cybercrime Methods

In order to protect oneself from cybercrime, one must need to know about the different ways in which computers can be compromised and privacy infringed. In this section, we discuss a few common techniques employed by the cyber criminals and will give a comprehensive idea of the loop-holes in networks and security systems, which can be exploited by attackers, and also their possible motives for doing so.

2.2 DDOS Attacks with botnets

DDoS stands for Distributed Denial of Service. This type of attack is used to bottle an online server with traffic that is much larger than the capacity it is designed for. This causes the service to become unavailable for legitimate users. Botnets are used for such attacks. These botnets are compromised computers that are remotely controlled by hackers and are used to perform all kinds of malicious activities including DDoS attacks by sending spam traffic.

2.3 Phishing and social engineering

This type of cybercrime is most common and is becoming increasingly popular during the work-from-home era. This type of attack involves the cybercriminals sending out dubious email attachments or links that redirect to malicious domains. Often proven social engineering techniques are used to trick users into revealing their secret information via these spam emails. Often cybercriminals would pose as customer service agents and gain your confidence by professional behavior. Later they would trick the user into revealing passwords or OTPs or access codes. These would enable the criminals to gain take control of your accounts and sell them online for monetary gains. A special type of phishing technique is spear phishing. These are specifically made to trick employees of an organization holding key access points, into revealing information. Extensive social engineering techniques are employed to gather background details about the employee such that the phishing emails can be designed to look as legitimate as possible. Verizon's report [3] in 2020 showed that 86% breaches were financially motivated, 22% of data breaches involved with a phishing email. As per a report by Google, there have been 18 million malware and phishing emails each day in April alone, with 240 million other spam mails each day [4].

2.4 Data Theft/ Online Identity Theft

In this type of cybercrime, the attackers employ a variety of techniques to gain access to the target's confidential information such as Personally Identifiable Information, financial information or even medical information. This information can be then used by hackers to conduct tax or insurance fraud, participate in criminal activities by opening a phone/internet account in the victim's name, claim government benefits or perform other imposter scams. In view of the pandemic situation, identity theft is quickly becoming a headache for people working from home. Statistics [5] shows that children and seniors are most likely to fall for identity theft. Malicious fraudsters target users' identity by setting up fake websites related to Covid19, spoofed government and health organization, fake job postings or sending mails related to miracle cures, free check-up or government aids.

Other cybercrimes include spam, data breaches, fraud, cyberstalking, cyberbullying and harassment, child predation, cyber extortion, social blackmail, stock market manipulation, cyber-espionage, attacks on critical infrastructure and information systems, and cyberterrorism.

Tools that are used to commit cybercrime without the victim's knowledge are called crimeware. They are intended to yield financial or other benefits to the attacker. Trojans, viruses, bots, keyloggers, backdoors, e-skimming, spyware, ransomware, scareware, adware, worms, malicious code, and denial-of-service are major examples of crimewares [6].

The following info-graphics demonstrate how the cybercrime rates have increased year-on-year basis:

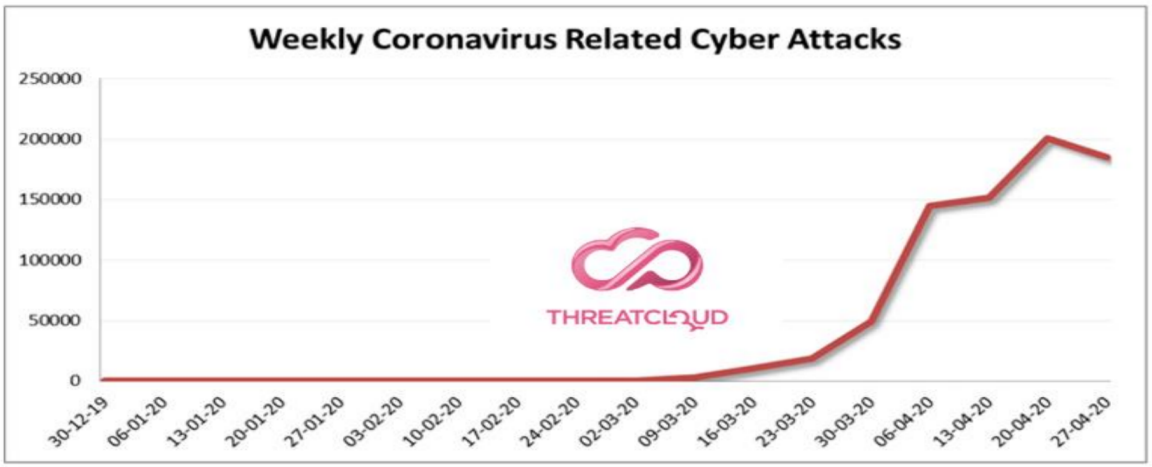
Table 1: Cyber-dependent crime and online fraud record in May 2019 and May 2020

	Count in May 2019	Count in May 2020	Relative Change (%)
Computer virus/malware/spyware	742	648	-12.67
Denial of Service attack	14	18	28.57
Hacking – Server	24	25	4.17
Hacking – Personal	270	479	77.41
Hacking – Social media and emails	939	1,449	54.31
Hacking – PBX/Dial Through	9	7	-22.22
Hacking combine with extortion	313	251	-19.81
Online fraud – Online shopping and auction	5,619	8,482	50.95
All cybercrimes	7,930	11,359	43.24

Table 2: Cyber-dependent crime and online fraud record in May 2019 and May 2020 [1]

		Count in May 2019	Count in May 2020	Relative Change (%)
Cyber-dependent crimes	Individuals	2.300	2,643	14.91
	Organization	260	222	-14.62
Online fraud – online shopping and auction	Individuals	5.408	8,220	51.99
	Organization	194	250	28.87
All cybercrimes	Individuals	7.708	10,863	40.93
	Organization	454	472	3.96

The following graph shows how the cyberattacks have varied with time since the start of this year [7].



3. Cybersecurity risk scenarios

Unlike regular crime, cybercrime is happening every moment in a large scale and the victims are totally unaware of it, until it's too late for them to realise. Any person can simply be doing whatever he/she usually does online, and without any warning, cybercrime can strike. This section tries to explain the most common scenarios that are vulnerable to cyber-attacks and some precautionary measures that one should always keep in mind while using the internet.

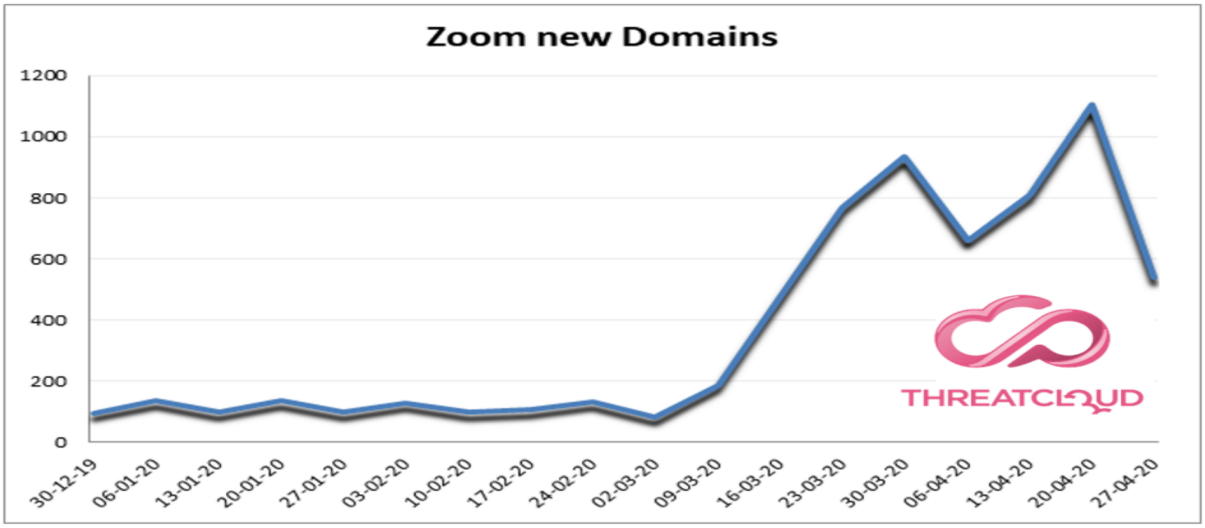
3.1 Risks at Work-from-home

The pandemic has forced the majority of employees to work from remote. Thus, they aren't working within the organization's secure perimeter. Often company leaders and higher-level staff need to access extremely sensitive information that could be accessed only from the workplace systems. Remote access to such computers or connections to those via Virtual Private Networks would be a huge risk for the security and integrity of a company. To prevent attack from cybercriminals, always-on-surveillance and real-time risk analysis of threats and breaches are needed. In this regard CERT-In, the country's nodal agency to counter cyberattacks has issued important advisories to protect people from cyberattacks [8,9].

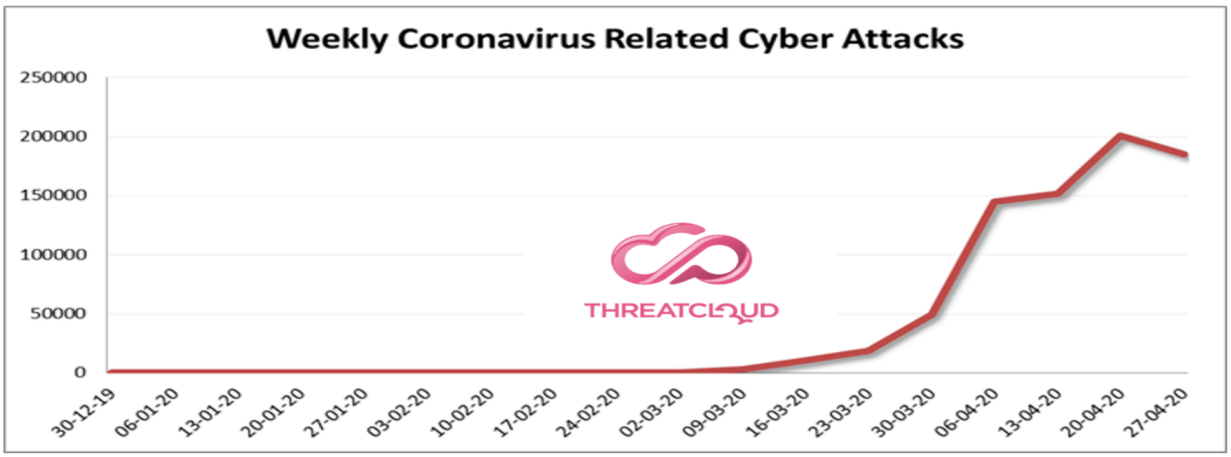
According to a research by Metova [10], as many as 18% of the participants replied that their employers did not have clear security and password guidelines. Another 31% believed work-from-home was less secure than working from the office. Video conferencing has become an integral part of the present WFH times. As many as 76% of all respondents in the Metova's survey responded that they were using video conferencing as part of their daily routine. Insecure network or compromised computers may lead to snooping by third party entities. Often common video conferencing apps may have an unpatched zero-day vulnerability, which may leave them susceptible to attacks. Some important points to keep track of are:

- Security Settings: By default, most video-conferencing apps require passwords to enter a video conference and the host's permission to let the user in, to prevent video bombing. Thus, all users should be made aware of when & how to use them. Hackers can exploit bugs or unattended user permissions to make recordings causing data leakage.
- Phishing: Apps like Slack, Microsoft Teams, and Zoom have messaging components that can be used by attackers to deliver phishing links.

As per a report by Checkpoint Research [11], since the beginning of the year, more than 1700 new domains were registered out of which 4% have been found to contain suspicious characteristics. New phishing websites have been spotted for every leading communication application, including the official classroom.google.com website, zoom, Microsoft teams, slack and others.



- Encryption: Often conferencing app vendors offer features such as automatic transcription, recording, facial recognition, real-time background replacement, noise reduction, echo cancellation, or audio mixing. These require the video stream to be decrypted to separate audio and video data to perform the mentioned activities. The data is usually sent to the vendor's server over encrypted channels. However, the data must travel through many private and public networks to reach its destination. If an attacker gains access anywhere in the path of this data stream, he can record and broadcast corporate secrets and intelligence. Thus, it is necessary to check if the vendor offers a high level of encryption like AES 128 bit or AES 256 bit.
- Post-video archiving: Often meeting metadata is required to be stored for record and future references. Information like these are extremely sensitive, thus need to be stored in secured and air-gapped networks. It is not recommended to store these types of data in personal computers as they can be vulnerable to malware [12].



Based on the joint survey by ISSA and ESG [13], a few important statistics can be noted:

a) 39% of respondents claim that they were very prepared to secure WFH devices and applications while 34% were prepared. 27% were underprepared.

b) 48% say that WFH has impacted the security team's ability to support new business applications/initiatives. Thus, the workloads of the members of the security team have increased.

c) An important consideration is that 70% report that they don't know or don't believe that this crisis will lead to cybersecurity becoming a higher priority. Only 30% say that cybersecurity will be a higher priority.

A couple of measures can be taken place to ensure security:

- Use of Cloud: Cloud-based security and platform services reduce the deployment time of the product. Also, cloud-based products are dynamically scalable. Cloud-based secure virtual desktop services give IT professionals remote access to employees' systems, including files and the network. Secure-edge, cloud-based data leakage prevention, and threat-protection controls can help safeguard an organization's critical assets. Moreover, cloud-based managed detection and response services can be extended to remote workplaces.
- Additionally, companies that use secure remote access technology can give remote employees private access (without a VPN) to enterprise applications and systems. Firms can also use privileged access management (PAM) services to allow special remote access to their IT and application administrators. Multi-factor authentication services including biometric and text-based methods enable stringent risk-based access to internal applications that are opened for remote access.

3.2 Risks in online trade and e-commerce

Following government restrictions on social distancing & lockdown, thousands of businesses had to close. Many physical stores, especially small businesses are likely to shut down. Certain fraudsters are setting up websites that mimic well-known retailers both in the URL as well as the look and feel of the websites. They offer essentials supplies at bargain prices which lures unsuspecting customers. The orders are faked and the fraudsters siphon out the payment information entered in those pages. Many businesses such as restaurants are dependent upon mobile applications to run in times of lockdown. Modified and malware infected apps downloaded from non-standard app stores can invite security risks. E-wallets and electronic methods of payment have become important as more and more customers are looking up to these as a solution to contactless payment. Unfortunately, UPI based payment fraud is rising in India, which stems mostly from inadequate knowledge among the masses about the proper usage of the same.

Organizations and individuals need to be aware of a lot of things during this period. A few important points are being highlighted here.

- Sales and distribution of goods: Prices of goods can be manipulated online causing artificial inflation. Similarly, the prices of shares and bonds can be influenced by hoarding.
- Fake websites: Fake websites selling goods at impossible pricing or requiring to pay the amount upfront may attract customers. Most of the time fraudsters disappear without delivering the goods.
- Adequate system audits: Both the consumer as well as business need to monitor, scan, and patch their devices from security vulnerabilities regularly to prevent bugs and exploits especially zero-day vulnerabilities.
- Education about e-payment methods: There has been tremendous growth in e-banking for the last few years due to the sustained push by the government. Proper education about performing transactions is needed for the mass to adapt to it. While the individuals are responsible, it should be the duty of banks and UPI providers to educate the user much more information actively through interactive mediums to engage the user.

3.3 Risks affecting businesses and enterprises

Business Email Compromise (BEC) [14] is one of the preferred methods via which fraudsters can compromise a company. They rely heavily on social engineering tactics to source useful information in order to trick their victims. Email accounts of executives or high-level employees, having the authority to control finance or involved with wire transfer payments are sourced from the internet via company websites, job posting portals like LinkedIn, Glassdoor or via social sites. The fraudsters then spoof the emails and send in emails to the unsuspecting employees that impersonate the CEO or similar highly ranked executives. This is popularly called as ‘CEO imposter Scams’. These emails may contain phishing links, word documents containing macro viruses or keyloggers that enable them to carry out fraudulent transfers. This can result in hundreds of thousands of dollars in losses.

A few cautious practices can prevent such scams [15]:

- Setting up of multi- user approval system that verifies the transaction via order id and approval from finance officers and managers.
- Approval of any changes to vendor payment information and funds request from the concerned people over phone.
- Avoiding transmission of account information, transaction id and other similar sensitive information via email.

Ransomware are a family of malware that demands ransom by restricting the access to the critical organizational data by encrypting them. They work by taking advantage of security vulnerabilities and make the systems unusable until a payment is made. Ransomware has been a problem for businesses even before the corona virus hit. Phishing mails and fraudulent websites are the major distributors of ransomware. Malware and ransomware themes with corona virus have been rampant in the first half of 2020 [16]. It is always advised by anti-virus vendors to not to pay the ransom as there is no guarantee that the files will be decrypted. The largest ransomware attack in history was the infamous WannaCry which hit some of the largest organizations of the world in May 2017. A report published in April 2020 by VMware Carbon Black noticed how ransomware attacks grew 148% on global organisations with the finance industry being heavily targeted [17]. Ransomware samples have risen by 72% in the pandemic period [18]. Regular security audit, application of security patches and upgrading to the latest software are the primary steps that should be followed to resist ransomware attacks.

4. Conclusion

The paper is an attempt to promote educational awareness regarding the most common threats looming in digital platforms during the pandemic period. It discusses the attacks that are gaining popularity during COVID-19 pandemic period. Attacks such as DDoS are mainly centered to disrupt the functioning of an organization resulting in huge loss of the revenue. The organization should always keep a plan ready in case of a DDoS attack and should always monitor its network if there is lack of performance. Attacks such as phishing, coupled with social engineering, are generally designed keeping individuals in mind and mostly try to extract money or to gain access to the personal computers of the victim. Identity theft is also one of the most common attacks. This paper also discusses various vulnerable situations which people are exposed to while working from home or exploring an e-commerce site to buy something and discusses various points to keep in mind in such situations. Finally, we see the various risks of the business enterprise and some precautionary measures to prevent from being a victim.

The work is one of the few papers relevant to this pandemic affected period that focuses on discussion about how the security risks have evolved to take maximum advantage of this situation. This study is done primarily keeping people in mind that have lesser knowledge about the various cyber-threats and the risk they pose to an individual or to an organization. By giving an insight into the motives behind such attacks and various vulnerable situations that a hacker tries to exploit to perform treacherous activities, one can be aware of the ways that lead to cyber-crime. Furthermore, it discusses some basic yet important points to keep in mind while surfing the net or while working remotely on a public network so that cyber-attacks can be avoided. As the security landscape evolves more study on this context can be done.

References:

1. D. Buil-Gil, F. Miró-Llinares, A. Moneva, S. Kemp and N. Díaz-Castaño, *Cybercrime and shifts in opportunities during COVID-19: a preliminary analysis in the UK,* European Societies, DOI: 10.1080/14616696.2020.1804973.
2. NYU School of Professional Studies, *Cyberpower and Global Security;* https://www.sps.nyu.edu/homepage/academics/courses/GSCC1-GC1015-political-cybercrime.html.
3. Verizon , *2020 DBIR Summary of Findings|Verizon Enterprise Solutions;* https://enterprise.verizon.com/resources/reports/dbir/2020/summary-of-findings.
4. K. Lyons, *Google saw more than 18 million daily malware and phishing emails related to COVID-19 last week;* https://www.theverge.com/2020/4/16/21223800/google-malware-phishing-covid-19-coronavirus-scams.
5. M. Mott, *Brain Changes as Trust Rises With Age;* https://www.nih.gov/news-events/nih-research-matters/brain-changes-trust-rises-age, Dec 2012.
6. A. Emigh , *The Crimeware Landscape: Malware, Phishing, Identity Theft and Beyond* [J. Digit. Foren. Prac. **1** (2006) 245]; DOI: 10.1080/15567280601049985.
7. ThreatCloud , *Coronavirus cyber-attacks update: beware of the phish;* https://blog.checkpoint.com/2020/05/12/coronavirus-cyber-attacks-update-beware-of-the-phish.
8. CertIN, *Coronavirus pandemic (COVID 19) based Cyber Attacks;* https://www.cert-in.org.in/s2cMainServlet?pageid=PUBADV01&CACODE=CICA-2020-2710.
9. CertIN, *Cert-In Advisory CIAD-2020-0008;* https://www.cert-in.org.in/s2cMainServlet?pageid=PUBVLNOTES02&VLCODE=CIAD-2020-0008.

10. Metova, *Infographic: 1000+ Respondents on Working from Home Due to COVID-19;* https://metova.com/infographic-work-from-home-covid-19.
11. Checkpoint , *COVID-19 Impact: Cyber Criminals Target Zoom Domains;* https://blog.checkpoint.com/2020/03/30/covid-19-impact-cyber-criminals-target-zoom-domains.
12. S. Gode , *Video Conferencing Security Issues and Opportunities;* https://www.unifysquare.com/blog/video-conferencing-security-issues-and-opportunities.
13. J. Oltsik, *The Life and times of Cybersecurity professionals 2020* (A joint report by ISSA-ESG , July 2020).
14. Trend Micro,*Business Email Compromise (BEC);*https://www.trendmicro.com/vinfo/us/security/definition/business-email-compromise-(bec).
15. S. Gressin,*CEO imposter scams: Is the boss for real?* https://www.ftc.gov/news-events/blogs/business-blog/2016/05/ceo-imposter-scams-boss-real , May 16,2016)
16. Trend Micro , *Developing Story: COVID-19 Used in Malicious Campaigns;* https://www.trendmicro.com/vinfo/us/security/news/cybercrime-and-digital-threats/coronavirus-used-in-spam-malware-file-names-and-malicious-domains.
17. J. Treinen and P. Upatham, *Amid COVID-19, Global Orgs See a 148% Spike in Ransomware Attacks; Finance Industry Heavily Targeted;* https://www.carbonblack.com/blog/amid-covid-19-global-orgs-see-a-148-spike-in-ransomware-attacks-finance-industry-heavily-targeted.
18. SkyBox Security , *2020 Vulnerability and Threat Trends Report;* https://lp.skyboxsecurity.com/WICD-2020-07-WW-VT-Trends_Reg.html.